Tracking The Time Course Of Language Understanding In Aphasia

Peter Hagoort

TRACKING THE TIME COURSE OF LANGUAGE UNDERSTANDING IN APHASIA

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op het gebied van de Sociale Wetenschappen

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INTRODUCTORY REMARKS

"Maar is dan ten opzichte der psychische processen iedere quantitatieve benadering uitgesloten? Geenszins! Een gewichtige factor scheen voor meting vatbaar: ik bedoel den tijd, die tot eenvoudige psychische processen wordt gevorderd."

F.C. Donders, 1869.

The major contribution of the Dutch physiologist Franciscus Donders to the study of the human mind has been his invention of experimental methods to measure the duration of mental processes. In contrast to the communis opinio in the nineteenth century, Donders held the view that the different mental processes intervening between stimulus and response do have a duration, which, moreover, can be determined for each of them separately (Draaisma, 1989). Donders thus made mental chronometry one of the corner stones of the research enterprise in cognitive psychology. In addition, he made us realize that the temporal characteristics of cognitive processes are among the most central aspects of human cognition.

Today's cognitive psychology is still very much in the middle of solving the puzzle that Donders left behind: what are the implications of the durational aspects of mental processes? However, since Donders the perspective on this puzzle of time and mind has changed. The crucial issue is no longer the determination of the absolute duration (and independence) of structurally unspecified mental events, such as feature extraction or response choice (the white boxology approach). Instead, the durational aspects of mental processes are now used as one of the major constraints in determining the internal organization of specific cognitive functions (the black boxology approach).

Let me illustrate this with an example from our cognitive ability to speak and understand words in a standard conversational setting. Psycholinguistic research has shown that listeners can recognize a spoken word within 200 msec from its onset (Marslen-Wilson & Tyler, 1980), and that speakers can easily produce three words per second (cf. Aitchison, 1987). Speaking and recognizing words requires access to the mental lexicon, which can be defined as the repository of declarative knowledge about the words of one's native language (Levelt, 1989). Recent estimations indicate that the mental lexicon of an educated adult contains information on at least 40.000 words (Nagy & Herman, 1987). One of the major problems to be solved by a theory of lexical access is the following: what enables the speaker/hearer to zoom in on the information about the words to be produced or recognized within a split second? It is obvious that the high speed of lexical access imposes strong constraints upon the internal organization of the mental lexicon and the nature of the access processes. Temporal constraints thus play an important role in the evaluation of different models of lexical access.

Lexical access is, however, only one component of the complex processes of listening (or reading) and speaking. Current theories on these cognitive skills dissect them into a number of subsystems (or functions) and processing components, which together constitute the functional architecture of the language processing system (cf. Levelt, 1989; Marslen-Wilson, 1987). A full account of language processing thus "requires a characterization of the representations that are computed by these processors and of the manner in which they are computed, as well as specification of how these components cooperate in generating their joint end product." (Levelt, 1989; p. 1). In order to generate this joint end product in a smooth and efficient way the temporal coordination between the various subprocesses is crucial. The different processing components must deliver their output at the appropriate moments in time, to enable an unhampered completion of the total process. Despite the relevance of the temporal organization of speaking and hearing, not much is known about the critical temporal bandwidth within which the processing components have to compute their representations and deliver their output, such that the process can run to its completion in an orderly manner.

One piece of evidence for the relevance of the appropriate time course of language processing might be obtained from aphasic deficits. Within the tradition of clinical aphasiology and neurolinguistics the role of time in both normal and impaired language processing has been stressed by a number of authors (cf. Kolk & van Grunsven, 1985). Von Monakow (1914) for example, introduced the concept of 'kinetic melody' to refer to his idea that the cerebral mechanism of language processing can be characterized as a series of successive activations which all have to appear at the appropriate moment in time. Lenneberg (1967) called time "the most significant dimension in language physiology" (p. 218), and stated that "almost all of the central nervous system disorders of speech and language may be characterized as disorders of timing mechanisms" (p. 218). The resulting symptomatology could be seen as arising from "a lack of availability at the right time." (p. 222). With respect to aphasic comprehension deficits he remarked that since language comprehension "has to progress with the same essential time characteristics as an individual's own production of discourse, it can be seen that a failure to understand may well be due to certain time-disorders in the hearer." (p. 219).

Empirical research bearing on temporal aspects of language comprehension in aphasia has mainly investigated the processing of sublexical (e.g., syllables) or non-verbal stimuli (Efron, 1963; Swisher & Hirsh, 1972; Tallal & Newcombe, 1978). Evidence was obtained that aphasic patients show a deterioration in temporally sequencing pairs of acoustic or even visual stimuli (e.g., a green and a red flash of light) if the interval between the two members of a pair is short (Efron, 1963; Tallal & Newcombe, 1978). Tallal and Newcombe (1978) also reported that increasing the duration of formant transitions in stop consonants improved the impaired discrimination for place of articulation in aphasic patients. Other studies, however, have failed to replicate this finding (Blumstein, Tartter, Nigro, & Statlender, 1984; Riedel & Studdert-Kennedy, 1985).

The starting point for this line of research was the presumed specialization of the left hemisphere for rapid temporal analysis, which has been assumed to be of special relevance for speech perception (Bradshaw & Nettleton, 1981; Poizner & Tallal, 1987; Tallal & Newcombe, 1978). A deficit in the analysis of rapidly changing acoustic events was hypothesized to underlie speech comprehension deficits in aphasia (Tallal & Newcombe, 1978). Other studies, however, have not been able to establish a direct connection between disorders of phonetic perception and general auditory comprehension deficits in aphasic patients (cf. Blumstein, 1987, 1990; Blumstein et al., 1984).

Until now, research into the temporal organization of lexical and post-lexical processing in aphasic patients has hardly been undertaken. Comprehension deficits might, however, be correlated with "a lack of availability at the right time" of representations computed at these stages of language processing. This thesis specifically investigates the time course of processes that follow after lexical access (e.g., lexical selection and integration). The general underlying assumption is that aphasic deficits in language understanding are not due to a loss of the knowledge required for the processing of language (e.g., words, syntactic specifications), but rather to an impairment in the on-line exploitation of these knowledge sources during the process of comprehension. The processing deficits focused on in the following chapters are assumed to have consequences for the temporal availability of specific types of information (e.g., lexical-semantic, syntactic, sentential-semantic).

In addition to the focus on possible changes in the time course of language comprehension in aphasic patients, the different studies reported in this thesis share a number of features, mainly at the level of experimental methodology. First, all studies are done with the help of an on-line task, namely lexical decision. Second, all studies are patient-group studies, testing mostly Broca's and Wernicke's aphasics in combination with different groups of control subjects. Finally, all experiments use the resolution of lexical ambiguity as the vehicle for testing the relevant hypotheses. The remainder of this chapter is devoted to explaining the choice for on-line tasks in general and lexical decision in particular, for patient-group studies, and for the use of homonyms.

Why on-line studies?

The experiments reported in this thesis (with one exception) use an on-line task, namely lexical decision. On-line tasks have two characteristics that are of special relevance for the study of comprehension deficits in aphasic patients. First, they tap the processes involved in language comprehension as they unfold in real time. In on-line tasks, listeners or readers are usually required to produce a response closely linked in time to relevant stretches of language input.[1] It is assumed that these responses are time-locked to the level of language processing one wants to study, such as access to the mental lexicon or construction of a syntactic and a semantic representation of the utterance. One advantage of on-line tasks is that listeners or readers do not have sufficient time to consciously reflect upon their response. This type of tasks severely limits the possibility of invoking heuristic strategies in producing a response, because the employment of strategies is generally assumed to require time (e.g., Posner & Snyder, 1975). Therefore, compared to responses in off-line tasks chances are higher that responses in on-line tasks tap aspects of language processing as it occurs in daily life.

Second, most on-line tasks do not entertain a transparent relation to the aspects of language processing being investigated. Lexical decision, naming, or word monitoring normally do not make subjects aware of the experimental manipulations. On-line tasks are implicit tasks in that subjects are not focused on the experimental variables that are of relevance to the issues addressed. Not all alleged on-line tasks share this implicit character. It does not apply, for instance, to a speeded grammaticality judgement task in which subjects are required to make a quick response if they detect a grammatical violation in the sentences presented to them (Shankweiler, Crain, Gorrell, & Tuller, 1989). For this reason it is doubtful whether speeded grammaticality judgements can be treated as a true on-line measure.

Until recently, the use of on-line tasks in research on comprehension deficits in aphasia has been very rare. The large majority of studies required aphasic patients to match sentences with pictures, to manipulate toy objects, or to give an explicit judgement with respect to specific aspects of the linguistic materials, such as its grammaticality or its semantic features. All these tasks are off-line in the sense that they tap the representations constructed during the process of language comprehension an 'eternity' after their construction has been completed. In off-line tasks patients are given a relatively large amount of time to produce their responses compared to the time needed for the construction of an interpretation for the presented utterance. This allows patients to invoke all the cognitive strategies available to them in solving the problem imposed by the experimenter. It leaves the possibility for the patient to make up for his/her deficits by using compensatory strategies, thereby masking the true nature of the underlying impairments in the functional architecture of the language processor.

How misleading it can be to take the patient's responses, or more general, his/her language behavior as a straightforward reflection of the underlying deficit, has been shown in research within the framework of adaptation theory (Heeschen, 1985; Heeschen, Ryalls, & Hagoort, 1988; Kolk, 1987; Kolk & van Grunsven, 1985; Kolk, van Grunsven, & Keyser, 1985). Adaptation theory has updated the distinction originally proposed by Jackson (1884) between positive and negative symptoms. Negative symptoms reflect the use of the impaired system. Positive symptoms, however, are produced by unimpaired mechanisms, which are only infrequently invoked in the language behavior of non-aphasic adults (Kolk & van Grunsven, 1985). Positive symptoms thus reflect the organism's adaptation to the damage, rather than the damage itself. The major evidence in support of adaptation theory is derived from the telegraphic style produced by agrammatic speakers. In contrast to the widely held view of telegraphic style as reflecting a syntactic deficit (cf. Berndt & Caramazza, 1980), adaptation theory stresses the grammatical correctness of telegraphic speech, which, it is claimed, obeys the syntactic constraints as they hold for context ellipsis (Kolk & van Grunsven, 1985).

Adaptation theory is first and foremost a theory of the language behavior of aphasic patients. It describes the language output of agrammatic patients as a positive symptom. The verbal behavior of aphasic patients is thought to embody an adaptation to their language deficit, with the form of adaptation depending on personality traits, awareness of the deficit, emotional status of the patient, the social environment, etc. (Heeschen & Kolk, 1988). However, adaptation theory does not provide us with an account of the underlying impairments to the functional architecture of the language processor.[2]

In this thesis I am mainly interested in the nature of the impairment, and not in the adaptive response strategies of the patient. Here, adaptation theory has important implications for the adopted research methodology. In order to open the window on the impairment, one has to remove the curtain of positive symptoms. That is, the task being used should constrain the degrees of freedom for adaptive behavior as much as possible. With respect to studies of comprehension deficits, on-line tasks therefore seem to be the most suited ones. Their implicit character and the time pressure they impose, minimize both the possibilities for and the success of adaptive response strategies, which probably guide the patient's performance in an off-line comprehension task (Caplan, 1983). This is one important reason for the use of an on-line task in the majority of the experiments reported in this thesis.

The other reason for the use of an on-line task relates to the topic of the studies. In one way or another, they all aim at tracking the time course of lexical processing in aphasia. Establishing the time course of language comprehension can only be done with tasks that tap its real-time characteristics. In this respect, the on-line methodology is the only president in town.

The two experimental tasks which are most widely used in on-line studies are lexical decision and naming. In the past years the field of psycholinguistics has seen a methodological debate about the costs and benefits of both tasks. This methodological debate has resulted in a general preference for naming over lexical decision, because the decision component of the latter task is claimed to make it more sensitive to post-lexical strategic effects than naming (e.g., Balota & Chumbley, 1984; Lorch, Balota, & Stamm, 1986; Seidenberg, Waters, Sanders, & Langer, 1984). Recent research, however, has shown that there are reasons to doubt the alleged superiority of naming over lexical decision (Brown, 1990). But even granting the supposed advantages of naming over lexical decision, in studies testing aphasic patients the costs of the naming task far outweigh its benefits. In research on comprehension deficits in aphasia, the production component involved in naming can severely interfere with both its validity and its reliability as an instrument to measure aspects of comprehension. Dysarthria seen in many Broca's aphasics and semantic paraphasias often produced by Wernicke's aphasics are just two examples in case. These production disturbances obviously affect naming but not lexical decision. For this reason I used the lexical decision task in the on-line studies to be reported.

Why patient-group studies?

In recent years, the neuropsychological community has seen an at times vehement debate about the scientific merits of patient-group studies. These merits are completely denied by Caramazza and his colleagues, who argue that inferences from impaired cognitive functions to the functional architecture of the unimpaired system can only be based on single-case studies (Badecker & Caramazza, 1985, 1986; Caramazza, 1984, 1986, 1988; Caramazza & Badecker, 1989; Caramazza & McCloskey, 1988; McCloskey & Caramazza, 1988). Against this strong position, others have defended the value of patient-group studies in neuropsychology, without denying the merits of single-case studies (e.g., Caplan, 1986, 1988; Zurif, Gardner, & Brownell, 1989). Although this is not the place for an extensive review of the arguments pro and con, I will briefly defend the choice for the patient-group studies presented in the following chapters.

Caramazza's argumentation against the group study methodology goes along the following lines. Neuropsychology differs from cognitive psychology in that experimentation in the former case is done by nature and not by the experimenter. Because the functional lesions to cognitive systems in brain-damaged patients are not a result of explicit manipulations by the experimenter, they can only be known after the researcher has uncovered the experimental conditions (i.e., the transformations of the cognitive system) created by each experiment of nature (Caramazza & Badecker, 1989). Inferences about functional lesions can only be based on the patient's performance on all the experimental tasks that are of relevance in the context of our current theories about the functional architecture of the particular cognitive system at issue. Whether two patients have identical functional lesions can therefore be established a posteriori, but not assumed a priori. In cognitive neuropsychology identity of functional lesions is a possible outcome of experimentation, but not a legal assumption to start with. However, in order to draw valid inferences from group studies, one must assume homogeneity of the group. That is, all subjects should have identical functional lesions. Otherwise inferences are based on averaging over differently impaired cognitive systems, thus leading to invalid conclusions with respect to their functional architectures. Caramazza argues that before all the experimental tasks are done, one has no psycholinguistically motivated selection criteria to make sure that the group is homogeneous with respect to the functional lesion. The methodological consequence is that "the basic unit of analysis in cognitive neuropsychology must be the individual patient" (Caramazza & Badecker, 1989; p. 259).

Let me begin with subscribing to the concern expressed in Caramazza's writings about possible problems in the interpretation of results averaged over patients. Group studies with brain-damaged patients are not without problems, but neither are single-case studies. One should be careful in interpreting the results of patient-group studies and always inspect the individual subject data to check whether they confirm or deviate from the overall group pattern. These and similar recommendations together form a set of practical heuristics for the interpretation of data gained from patients with a functional lesion in one of their cognitive systems. The disagreement, however, is not about the advice that we should be as careful as possible, but about the call that we should not be engaged in patient-group studies at all. Here, I will give three arguments against the position taken by Caramazza and his colleagues. The first one concerns their implicit view on science. The second concerns the principled distinction that Caramazza makes between experiments with brain-damaged patients in cognitive neuropsychology and experiments with neurologically unimpaired subjects in other branches of cognitive psychology. The third argument is on the problem of reliability that arises for data obtained in single-case studies.

The first argument is derived from philosophy of science. Reconstructions of relevant episodes in the history of science have shown that chances for scientific progress do not increase by prescribing one and forbidding another methodology (cf. Feyerabend, 1963, 1975). The road to knowledge is much less predictable than the advocates of a fixed set of methodological maxims implicitly believe. Not having a preference for one specific methodology, of course does not imply a defense of sloppy research. However, I am sceptical about the possibility of constructing a royal route to knowledge by paving it with strict methodological prescriptions. In general, the outcome of scientific research decides a posteriori what has been the most fruitful methodology. Caramazza's diatribe against patient-group studies is unjustified in its attempt to block roads to knowledge that have not yet had full opportunity to prove whether or not they lead to scientific progress.

The second argument is related to Caramazza's opinion on the fundamental difference between neuropsychology and all other experimental sciences. The following quote from Caramazza and Badecker (1989) emphasizes this position: "The situation we have described differs in a fundamental way from the typical experimental procedure in other sciences. Unlike these other sciences we do not start with some theory, make *predictions*, set up an experiment, get the results, and then on the basis of the results determine whether the theory's predictions were confirmed. In cognitive neuropsychology, a theory is preferred to another theory if on the basis of a patient's performance we can hypothesize a functional lesion to one theory, but not to an alternative theory, such that the functionally lesioned theory can generate the observed performance." (p. 259). In other words, patient data can only be used to select the best candidate from among a series of preexisting theories about the functional architecture of the cognitive system under study.

I do not find myself particularly convinced by this line of argumentation, because I disagree with the reasons for setting apart neuropsychological inquiry from other branches of cognitive science. The proposed apartheid for cognitive neuropsychology is related to the claim that the homogeneity assumption is justified for groups of neurologically unimpaired subjects, but not for groups of brain-damaged patients. I believe that this opposition is the consequence of a false dichotomy between experiments of nature and experiments of science. It ignores the fact that not only impaired but also unimpaired functional architectures are experiments of nature.

In research on unimpaired subjects we start off with the assumption that all our subjects have identical functional architectures, although a pressing reason to assume a priori that nature has created human species this way is lacking. On the contrary, from a biological perspective variation is much more likely than homogeneity. With respect to our language faculty Lieberman (1984) remarks that "to the degree that human linguistic ability involves genetically transmitted neural and anatomical mechanisms, we must expect variation." (p. 334). In our experimentation we abstract away from this biological variation, under the assumption that it has no far-reaching consequences for theories about the general functional architecture of our cognitive apparatus. Therefore, we treat results of a subject who deviates from the averaged group performance as random noise instead of meaningful variation. Therefore, we generalize our findings with young, highly educated subjects to populations with a much larger variation in age, education, etc. What will eventually justify the homogeneity assumption is nothing else than the success of the scientific enterprise that takes it as one of its starting points. Its failure might indicate that we have been wrong in ignoring the variation in cognitive skills of different subjects.

Thus, Caramazza's suggestion that nature has created uniformity in neurologically unimpaired subjects and variation in patients with a lesion is debatable. Compared to neurologically unimpaired subjects, variation between patients might be larger, establishing the criteria for selecting members from the population of interest might be more difficult, etc. All this makes cognitive neuropsychology relatively complex. But these gradual differences do not create a principled distinction between cognitive neuropsychology and the rest of cognitive science.

Caramazza does not seem to sufficiently realize how theory dependent the notion of homogeneity is. In all cases homogeneity is only required with respect to aspects of the theoretical issues addressed in the experiment. Studies on word recognition do not require that subjects have the same length or weight. These factors are assumed to be completely irrelevant with respect to the process of word recognition. Of course, this might turn out to be wrong. In the same way, the theoretical questions in neuropsychological research will determine whether homogeneity with respect to the nature, size and location of the lesion is relevant or not. For many questions it is relevant, but nothing tells us that it will be relevant for all theoretically interesting issues in cognitive neuropsychology. Within the theoretical framework that guides the experimental research, the educated guess that homogeneity holds for the selected population (e.g., unimpaired language users, agrammatics, deep dyslexics) is valid until the data force us to reconsider the homogeneity assumption. Violations of the homogeneity assumption might be indicated by the absence of significant experimental effects due to between-subject variation or by the impossibility to interpret the data in terms of existing theoretical models.

Let me illustrate my argument with the following example. Suppose that on the basis of whatever kind of evidence one formulates the theoretical hypothesis that all aphasic patients with a comprehension deficit as uncovered by a formal test battery, suffer from slower-than-normal lexical processing due to a slower-than-normal rise time of the activation of lexical items (cf. Swinney, Zurif, & Nicol, 1989). Moreover, the severity of the comprehension deficit is assumed to correlate with the amount of delay in activation rise time. On this account, the functional architecture of the system itself is not affected, but the temporal constraints under which it operates are. Given this hypothesis, the assumption of homogeneity with respect to the nature of the functional impairment seems perfectly valid for a group of aphasic patients with a comprehension deficit. It remains valid as long as it is not falsified by the data. One is of course free to find the research question uninteresting, or the theoretical hypothesis unlikely. However, I do not see any compelling methodological reason for the claim that this question is scientifically unsound or untestable in a group study.

Given the theoretical claims, in this particular case a group study is even to be preferred over a single-case study. In other words, the content of the theoretical claims decides whether single-case or patient-group studies are the most appropriate. The results of the experimental tests in which the theoretical claims are brought under empirical scrutiny, play a decisive role in establishing their survival value. A violation of the homogeneity assumption can only be established a posteriori. I do not see that in this respect the state of affairs in cognitive neuropsychology is fundamentally different from "the typical experimental procedure in other sciences".

Finally, a third argument concerns the reliability of group studies versus single-case studies. In chronometric studies on psycholinguistic processes such as lexical access or parsing, there are almost always individual subjects that do not show the overall group effect. This individual variation is usually interpreted as noise in the data which arises for theoretically uninteresting reasons (e.g., lack of attention, fatigue, etc.). The often small magnitude of the effects and the noise in the data render single-case analyses unreliable. Group studies in psycholinguistics are assumed to magnify the small, theoretically interesting effects and to reduce the masking influence of experimental noise (Caplan, 1988). In order to obtain a reliable database, most on-line tasks in current psycholinguistics therefore require group studies.[3] So, Caramazza's proviso implies that most of the on-line tasks used in psycholinguistics can no longer be applied (reliably) in studies on patients with a language deficit. This would certainly be a serious drawback for studies on aphasia. As an aside I should add that the statistical analysis of group data has its own built-in protection against serious violations of the homogeneity assumption. Strong violations of this assumption with respect to the theoretical issue addressed in the experiment, will very often lead to a lack of statistical significance. Null effects are standardly interpreted as failures to confirm the theoretical predictions. The chance that a patient group consisting of patients with completely different functional lesions will bring about a significant effect that critically depends on one particular functional lesion, seems very small indeed.

In conclusion, the costs of giving up patient-group studies altogether in cognitive neuropsychology do not outweigh the benefits of a methodological unification in the form of a single-case approach. Given the issues addressed and the experimental task used in this thesis, patient-group studies seem to be more appropriate than single-case studies.

Why homonyms?

All studies in this thesis use the resolution of lexical ambiguity in homonyms as a vehicle to study the time course of lexical processing in different types of context.

Homonyms are spoken words with at least two unrelated meanings (e.g., *bank*). Because both meanings have the same word form, contextual information is required to determine which of the meanings is the intended one. The number of these kinds of ambiguous words in a language is restricted. However, indeterminacy of meaning is a pervasive phenomenon. Most words have more or less different senses according to the context in which they appear. In the absence of a sufficiently developed theory of the semantics of natural languages, it is problematic to draw a clear formal boundary between ambiguous words with multiple meanings and unambiguous words with multiple senses. For most experimental purposes, however, the difference between words with multiple meanings and words with multiple senses is more a matter of expediency than of principle (cf. Simpson, 1984).

Ambiguous words have been extensively used in studies on the influence of contextual information on lexical processing (for a review, see Simpson, 1984; for a representative collection of studies, see Small, Cottrell, & Tanenhaus, 1988). The studies in this thesis also use lexical ambiguity in a strictly instrumental way, in this case to answer questions with respect to the time course of lexical processing in different types of contexts.

Unlike for English (e.g., Gorfein, Viviani, & Leddo, 1982; Kreuz, 1987; Nelson, McEvoy, Walling, & Wheeler, 1980), a list of Dutch words with multiple meanings was not available. Such a list had to be constructed in order to carry out the experimental studies. Moreover, association norms were collected for each ambiguous word, and the relative frequency (dominance) of each meaning was established.[4]

Structure of the thesis

The next four chapters of this thesis contain descriptions and discussions of the experimental work. Each chapter is written in such a way that it can be read independently from the other chapters. In a few places this has led to some overlap in the introduction to the experiments or in the method section. The modular structure of the thesis made this unavoidable.

Chapter two presents data on the processing of homonyms in a priming context. Only results for neurologically unimpaired subjects will be reported. This chapter mainly serves the purpose of a methodological discussion about the criteria that the data of control subjects should meet in order to allow the interpretation of patient data in terms of psycholinguistically motivated models of language processing. To illustrate the points I want to raise, results reported by Milberg, Blumstein, and Dworetzky (1987) are criticized. Except for the postscript, chapter two has been published in *Brain and Language* (Hagoort, 1989b). The postscript is added in answer to the reply by Milberg and Blumstein (1989).

Chapter three presents a study on the processing of homonyms in a priming context by Broca's and Wernicke's aphasics. It tests the claims that Broca's aphasics are selectively impaired in automatic lexical-semantic processing, and Wernicke's aphasics in controlled lexical-semantic processing. To separate contributions of automatic and controlled processing to the overall priming effects, three different time-intervals between primes and targets were used, ranging from 100 to 1250 msec. In addition, in a separate experiment patients were asked to explicitly judge the semantic relations between the primes that were used in the lexical decision task. This was done to investigate the influence of task aspects on the results. Parts of the data reported in this chapter were presented at the Annual Meeting of the Academy of Aphasia in October 1988 in Montreal.

Chapter four investigates the time course of the resolution of lexical ambiguity in a sentential-semantic context. Neurologically unimpaired subjects have been shown to very rapidly select the meaning that fits into the context (cf. Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). This chapter addresses the question whether Broca's and Wernicke's aphasics are as efficient as normal subjects in selecting the context-appropriate reading of the ambiguity. The results are assumed to allow inferences with respect to possible delays shown by aphasic patients in the time course of integrating lexical meanings into the representation of the sentential-semantic context.

Chapter five uses ambiguous words for which the two meanings belong to different form classes (i.c. noun-verb ambiguities). These ambiguities are presented in a syntactic sentence context which biases one particular meaning via a syntactic constraint on the possible form class. Again, the time course of the ambiguity resolution is investigated. In this case, only Broca's aphasics are selected to participate next to the control groups. The question to be answered is whether the agrammatic patients can use syntactic context information on-line to select the syntactically allowed reading of the ambiguity, and if so, whether syntactic selection is completed within the time frame that was obtained for the unimpaired language processor. The data reported in this chapter were presented at the Annual Meeting of the Academy of Aphasia in October 1990 in Baltimore.

Finally, in chapter six I will try to further determine the nature of the processing deficits in Broca's and Wernicke's aphasics on the basis of the experimental results that were discussed in the previous chapters.

2

PROCESSING OF LEXICAL AMBIGUITIES: A COMMENT ON MILBERG, BLUMSTEIN, AND DWORETZKY (1987)

In a number of recent studies using a semantic priming paradigm with a lexical decision task, it has been demonstrated that Wernicke patients produce essentially the same pattern of results as normal control subjects, whereas Broca patients seem to be less or not at all sensitive to prime-target relations (Milberg & Blumstein, 1981; Blumstein, Milberg, & Shrier, 1982; Milberg, Blumstein, & Dworetzky, 1987). This differential outcome is most clear in the recent Milberg et al. study (1987), which is based both in design and materials on Schvaneveldt, Meyer and Becker's work (1976) on the processing of lexical ambiguity in normal subjects. The Milberg et al. findings are intriguing, not in the least because of their clear discrepancy with the standard view that lexical-semantic processing is especially disturbed in Wernicke patients, whereas it is not or less disturbed in Broca patients (see Caramazza & Berndt, 1978).

The logic underlying most modern psycholinguistically-oriented work in aphasiology is that conclusions as to the functional deficits of aphasic patients are to be based upon a comparison of their performance with that of normal speakers, in experimental situations which reveal significant aspects of language processing. That is, the data for the normal group are to serve as a baseline, in the light of which the pattern of results for the aphasic patients is to be interpreted. What is presupposed is that one can account for the normal data in terms of well-established psycholinguistic models.

Following this two-step reasoning, Milberg et al. (1987) first report that their results for normal subjects are "similar to those reported by Schvaneveldt, Meyer and Becker (1976)" (pp. 144-145). In agreement with the latter authors, the normal subject data are interpreted as evidence in favor of a "selective access" model for the processing of ambiguous words. That is, of the separate meanings of a lexical ambiguity, only the one that fits the prior semantic context is said to be accessed. The results for the groups of Wernicke's and Broca's aphasics are subsequently interpreted with reference to the normal processing model: Wernicke patients "show, as do normals, selective access to different meanings of ambiguous words", whereas "the lack of semantic facilitation in any of the priming conditions for the Broca's aphasics supports the intriguing possibility that these patients have a deficit in the processing of semantic information" (p. 147). In this note, the first step in the two-step argument is addressed, in that the "similarity" with the Schvaneveldt et al. data will be questioned.

Milberg et al. used four of the six prime conditions and a subset of the triplet materials from the Schvaneveldt et al. (1976) study, where the final elements were either words or pronounceable nonwords. In the critical word target set, the triplets consisted of two primes and a target. In three of the four priming conditions the second prime was an ambiguous word. In the *concordant* condition, the first prime and the target were related to each other and to just one meaning of the second, ambiguous prime (e.g., *coin-bank-MONEY*). In the *discordant* condition, the first prime was related to one meaning of the ambiguity, whereas the target was related to another (e.g., *river-bank-MONEY*). The *neutral* condition consisted of triplets in which the first prime was unrelated to the middle ambiguous prime, while the target was related (e.g., *desk-bank-MONEY*). The *unrelated* (baseline) condition consisted of three unrelated, unambiguous words (e.g., *nurse-fish-MONEY*).[1] The triplets were presented auditorily, and the subject's task was to make a lexical decision about the final target element.

With the semantic word-contexts provided by these materials, what is being measured with a lexical decision task is the effect of intra-lexical priming, which is usually taken to be a function of the semantically based organization of the lexical network and of the automatic spread of activation to related elements (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). This type of lexical context effect can be accounted for not only within interactive models of word recognition, but is also easily incorporated within a modular view on the processes of word recognition (Forster, 1979), and does not contradict the reported findings of multiple access in a non-lexical semantic context (Seidenberg et al., 1982; Swinney, 1979).

Within the context of intra-lexical priming, "selective access" is the activation of only that meaning of an ambiguous word which is biased by the meaning of a preceding word. For the research under discussion, it means that activation from the first word in the triplet spreads only to the *related* meaning of the ambiguous word, which gains further activation with the presentation of the ambiguous word itself. In consequence, there is an automatic bias as to which reading of the ambiguous word is selected by the context. The extent to which activation is carried through to the target word depends upon the direction of the reading selection within the prime pair. In the discordant condition, no priming effect is expected because the meaning of the target word (e.g., *MONEY*) relates to a reading of its immediately preceding ambiguous prime other than the one selected by the initial prime (e.g., *river-bank*). The account here spells out Milberg et al.'s assumption that the discordant condition should gain no facilitation relative to the baseline, where two unambiguous primes are each unrelated to the target. In the neutral condition neither reading of the ambiguous word benefits from the activation spread from the unrelated first word. Therefore, on presentation of the ambiguous prime itself, either both readings get some activation, or perhaps stochastically, the one related to the target is accessed in some instances, and in others the alternative unrelated meaning (Schvaneveldt et al., 1976). Whichever of these possibilities might be correct, they both predict more facilitation for the neutral condition than for the discordant condition. Thus Milberg et al. summarize by saying that if there is "more facilitation for the neutral condition than the discordant condition, and if the discordant condition produced no facilitation relative to the baseline condition, then it would suggest that ... access ... was selective (i.e., it was affected by context, namely, the semantic representation of the first prime word)." (p. 142).

However, this picture cannot be complete without a consideration of the concordant condition, so far omitted in this outline of a selective access hypothesis. To accord with that hypothesis, responses to targets in the concordant condition should be faster than in all other conditions, and certainly there should be significantly more facilitation than in the discordant condition. With concordant primes, activation from the first word not only spreads to the target-related reading of the ambiguous word, but also to the target itself (Schvaneveldt & Meyer, 1973). On the basis of the logic that underlies predictions for the neutral, discordant and unrelated conditions, one should expect the greatest facilitation for the concordant primes. And that is exactly what Schvaneveldt et al. found in the experiments they reported. Table 1 summarizes these data and compares them with the normal subject data of Milberg et al. (1987).

Although Milberg et al. report that their results are "similar" to those of Schvaneveldt et al. (1976), closer inspection reveals, critically, that priming in the concordant condition is neither greater than in the neutral condition nor securely different from the discordant one. The selective access hypothesis which is consistent with the Schvaneveldt et al. results

TABLE 1

Mean visual (Schvaneveldt et al.) and auditory (Milberg et al.) lexical decision times (RT) as a function of Priming Condition.

	Schvaneveldt et al. (1976)				Milberg et al. (1987)	
Priming Condition	Expt. 1	d	Expt. 2	d	Expt. 1	d
Concordant	505	33	617	54	779	33
Discordant	558	–20	662	9	792	20
Neutral	521	17	635	36	767	45
Unrelated	538		671		812	

Differences (d) are measured relative to the unrelated baseline. The data of Milberg et al. are reconstructed from their Figure 1 (p. 145).

is not fully consistent with the pattern in the Milberg et al. study, examined in this detail. In short, the claim of similarity is unwarranted, and the data of Milberg et al. for their *normal* subjects remain in need of a coherent story. And this is a matter for real concern, since a more precise account of the aphasic deficits in terms of the selective access model adopted for the unimpaired subjects is thereby excluded.

Is there a possible explanation for the discrepancy between the results of Milberg et al. on the one hand and those of Schvaneveldt et al. on the other? A first difference between both studies is a procedural one: the subjects of the Schvaneveldt et al. experiments responded to each element of the visually presented triplets, while Milberg et al.'s subjects responded only to the triplet-final target, under auditory presentation. A second contrast with the earlier study concerns the design: Milberg et al.'s subjects heard every target word in all four priming conditions. It is possible that this degree of intimacy with the experimental materials and, thereby, with the structure of the experiment might introduce special strategies, so that, for example, subjects might attend to both meanings of the ambiguous word under attentional control. Further, the possibility cannot be ruled out that semantic priming effects were 'polluted' by repetition effects, given that the same target word was presented four times to each subject (Scarborough, Cortese, & Scarborough, 1977). Apparently, Milberg et al. did not explicitly control in their design for possible effects of repetition: their single, fixed presentation order is reported to be random, not pseudorandom as is required to control for possible repetition effects.

To find out whether one (or maybe both) of these latter factors played a role in the findings of Milberg et al., two replication studies with auditory presentation were run, one in which no subject heard a specific word more than once and one in which the same design was used as in the Milberg et al. study, but with a counterbalancing to control for possible repetition effects.

Experiment 1

Experiment 1 was intended to be a close replication of the Milberg et al. experiment, with three changes. First, the stimulus assignment counterbalanced words across subjects, so that no individual subject heard the same word more than once. Second, the test language was Dutch, rather than English. Third, type of ambiguity was introduced as a separate factor, since there is some experimental evidence that in a priming context there is selective access for noun-noun ambiguities, but multiple access for noun-verb ambiguities (Seidenberg et al., 1982). Thus, one half of the ambiguous words in the experimental sets consisted of noun-noun ambiguities (e.g., *pupil*; "pupil/pupil"), and the other half consisted of noun-verb ambiguities (e.g., *varen*; "fern/to sail").

Method

Subjects
Forty subjects from the subject pool of the Max Planck Institute for Psycholinguistics participated in this experiment. All were native speakers of Dutch, and were paid for their participation.

Materials
The stimuli in this study consisted of triplets in which the first and second members served as primes and the third as target. In three of the four priming conditions for real word targets, the second prime was a word with two or more unrelated meanings. The stimulus words were taken from an extensive pretest of 190 ambiguous Dutch words, in which the relative frequencies of the distinct meanings as well as the first associates in the distinct semantic fields were established for each ambiguity. This pretest was done with 70 subjects, mainly students from the University of Nijmegen. From this initial set of materials, 16 noun-noun ambiguities, 15 noun-verb ambiguities, and 1 adjective-verb ambiguity were selected, all with a relatively strong associate for both meanings (with a mean of 48%

of agreement in responses given for each semantic field; for the set of experimental word triplets, see Appendix 1). One associate was used as the triplet-final target. A second order associate for the ambiguous words was established via a second pretest, in which subjects were presented with a pair consisting of the ambiguous word preceded by the associate of one reading in one version of this pretest, and by the associate of the other reading in the other version. The subjects were instructed to write down a word to complete the triplet. By this procedure the set of first primes for the experimental word triplets was established.

As in the Milberg et al. (1987) study, there were four priming conditions for word targets. In the concordant condition, the first prime and the target were associated with the same meaning of the second (ambiguous) word prime (e.g., *bier-kater-DRANK*; "beer-tomcat/ hangover-DRINK"). In the discordant condition, the first prime and the target word were associated with different meanings of the second prime (e.g., *poes-kater-DRANK*; "cat-tomcat/hangover-DRINK"). In the neutral condition, the first word was unrelated to the second, but the third word was related to one of the meanings of the second word (e.g., *piano-kater-DRANK*; "piano-tomcat/hangover-DRINK"). Finally, in the unrelated condition, the three words were unrelated and unambiguous (e.g., *poes-piano-DRANK*; "cat-piano-DRINK"). In addition to the 32 word triplets, there were 32 triplets in which the target was a pronounceable nonword, and the primes were previously unused words. In half of these nonword triplets, the first two words were unrelated and unambiguous (e.g., *hemd-ketel-REFEL*; "shirt-kettle-REFEL"); in the other half, the second word was ambiguous and the first was related to one of its meanings (e.g., *ladder-sport-ZORWAAL*; "ladder-rung/sport-ZORWAAL").

The test stimuli were arranged in two blocks: one block of 16 noun-noun word and 16 noun-noun nonword triplets, and a second block of 16 noun-verb word (including one adjective-verb triplet) and 16 noun-verb nonword triplets. Each block was preceded by 12 startup trials. In addition, every test session started with 20 practice triplets to acquaint the subjects with the procedure.

All materials were spoken by a female speaker in a sound-proof booth and recorded on a Revox A 700 tape recorder. The stimuli were digitized and stored in a VAX 750 computer with a sampling rate of 20 kHz. Four test tapes were then constructed for the four versions of the experiment. In each version a test block consisted of 4 concordant, 4 discordant, 4 neutral and 4 unrelated word triplets and an equal number of nonword triplets. The triplet assignment counterbalanced the words across subjects so that no individual subject heard the same item more than once. There was a 4-sec interval of silence between each triplet and a 0.5-sec interval of silence between each item within a triplet. The input to and the output from the computer were low-pass filtered with a cutoff frequency of 10 kHz.

Apparatus
The apparatus for the experiment consisted of a Revox B77 stereo tape recorder, a Miro GD laboratory computer, a pulse-read unit, two pairs of headphones (one pair for the subject and another for the experimenter), and a response keyboard with a YES button on the right side of the board and a NO button on the left. The test stimuli on the left channel of the tape were played binaurally to the subject, while pulses on the right channel of the tape at the onset of the targets, inaudible to the subjects, started a millisecond timer. The timer was stopped as soon as the subject pressed one of the buttons, and the data were automatically stored. The time-out was set to 2 seconds.

Procedure
Subjects were assigned randomly to one of the four experimental versions (i.e., ten subjects in each version). Each subject was tested individually in a single session lasting approximately 25 minutes. Subjects were seated in a sound-proof booth with the keyboard placed in front of them, pressing the YES button with the right index finger and the NO button with the left.

Subjects were told that they would hear a series of triplets either ending with a word or ending with a nonword, and were instructed to respond to the third member of the triplet as quickly as possible, indicating whether it was a word by pushing the YES button or a nonword by pushing the NO button. After the practice items, the subjects were asked to increase the speed of responding without losing accuracy. No further feedback was given during the testing session.

Results

The analyses that will be reported are on the reaction time data only, since the error rates were rather low: 2% for the words, and 3% for the nonwords. The effects of Priming Condition (4 levels) and Type of Ambiguity (2 levels) were tested in two analyses of variance, a subject analysis (F_1) and an item analysis (F_2). A summary of the results is presented in Table 2.

There were significant main effects of Priming Condition ($F_1(3,117)=24.9$, $p<.001$; $F_2(3,90)=23.4$, $p<.001$), and Type of Ambiguity ($F_1(1,39)=226.2$, $p<.001$; $F_2(1,30)=16.0$, $p<.001$), but there was no significant interaction between these factors (F_1 and $F_2 < 1$).[2]

TABLE 2

Mean auditory lexical decision times (RT) for Experiment 1 as a function of Priming Condition.

Priming Condition	RT	d
Concordant	621	75
Discordant	689	7
Neutral	667	29
Unrelated	696	

Differences (d) are measured relative to the unrelated baseline.

Post-hoc comparisons were carried out on the means of the four priming conditions using the Newman-Keuls procedure (with the relevant error term from the subject analysis and the item analysis, separately), and with the significance level set at .05. These indicated in both cases that the concordant condition resulted in faster reaction times than all other conditions. Further, the neutral condition was significantly faster than both the discordant and the unrelated conditions, and there was no significant difference between the discordant condition and the unrelated baseline.

Discussion

These results replicate the original findings of Schvaneveldt et al., despite differences in modality of presentation (visual vs. auditory), experimental procedure (decisions on every word of the triplet vs. decisions on the final item of the triplet), and materials and language used. In contrast, despite the same modality of presentation and the same procedure as in the Milberg et al. study, this study fails to replicate their results in important respects. In accordance with the selective access hypothesis, but in contrast to the Milberg et al. results, a significant difference in the right direction between the concordant and the neutral condition was found. The most obvious possible cause of discrepancy is the design in the Milberg et al. study, either leading to strategy effects or to repetition effects for which no control was built in. Therefore, a second experiment was run with the same materials, but with a design in which all subjects heard all the experimental items in every condition in one and the same experimental session. However, in contrast to the Milberg et al. study, Experiment 2 controlled for possible effects of repetition.

Experiment 2

Method

Subjects

Twelve subjects from the subject pool of the Max Planck Institute participated in this experiment. They were paid for their participation.

Materials

The 128 word triplets were the same as in Experiment 1: 32 triplets in the concordant condition, 32 discordant, 32 neutral, and 32 unrelated. In half of the 64 nonword triplets an ambiguous prime was followed by a word related to one of its meanings; in the other half, the first and the second primes were unrelated and unambiguous. Every nonword triplet appeared twice in the experimental session. In this way, the materials were constructed in exactly the same way as in the Milberg et al. study. However, unlike the Milberg et al. procedure, the order of the four experimental word-target conditions was explicitly counterbalanced among triplets. This was done by taking two random samples of 16 from the 24 possible condition orders, one for the block of noun-noun items and one for the block of noun-verb items. These 16 orders were assigned randomly to the 16 basic word triplets per block. In this way, potential repetition effects due to presenting the same target word four times could be controlled.

The full experiment thus had 256 experimental triplets, presented in 2 blocks of 128. Every block was preceded by 12 startup items. The experimental session began with a set of 20 practice items to familiarize subjects with the task.

Procedure

Subjects were run individually, each session lasting approximately 45 minutes, with the procedure as in Experiment 1. There was a short break between blocks 1 and 2.

Results

Again, the error rates were low (0.8% for the words, and 3.6% for the nonwords), so that analyses were carried out on reaction time data only. The results are summarized in Table 3.

TABLE 3

Mean auditory lexical decision times (RT) for Experiment 2 as a function of Priming Condition.

Priming Condition	RT	d
Concordant	596	52
Discordant	656	−8
Neutral	622	26
Unrelated	648	

Differences (d) are measured relative to the unrelated baseline.

Analyses of variance tested the effects of Priming Condition and Type of Ambiguity. There were significant main effects for Priming Condition ($F_1(3,33)=19.6$, $p<.001$; $F_2(3,90)=8.0$, $p<.001$) and Type of Ambiguity ($F_1(1,11)=67.8$, $p<.001$; $F_2(1,30)=7.6$, $p<.001$). There was, however, no significant interaction between Priming Condition and Type of Ambiguity ($F_1(3,33)=1.29$, $p>.25$; $F_2 < 1$).

Post-hoc comparisons between the means of the four priming conditions were made, as in Experiment 1. A Newman-Keuls test using the error term from the subject analysis revealed significant differences ($p<.05$) between all pairs of means, except - as in Experiment 1 - for the discordant versus the unrelated comparison. Using the error term from the item analysis, similar results were obtained with the exception that the difference between the concordant and neutral conditions failed to reach significance.

In addition to the effects for Priming Condition and Type of Ambiguity, the effect of repetition of target words was also tested, since every subject heard the same target word four times. In this analysis, all target words with the same index of presentation (first, second, and so on) were collapsed. Analyses of variance with Index of Presentation (4 levels) as factor, showed a highly significant effect ($F_1(3,33)=19.9$, $p<.001$; $F_2(3,93)=13.7$, $p<.001$). The results are summarized in Table 4.

TABLE 4

Mean auditory lexical decision times (RT) in Experiment 2 as a function of Index of Presentation.

Index of Presentation	RT	d
First Presentation	678	
Second Presentation	627	51
Third Presentation	614	64
Fourth Presentation	603	75

Differences (d) are measured relative to the first presentation.

Post-hoc Newman-Keuls tests revealed significant differences ($p<.05$) between the first presentation of the target words and all the following presentations. A separate analysis of variance on the means for all items with the same index of presentation within every priming condition, showed a significant interaction between Priming Condition and Index of Presentation ($F_1(9,99)=2.4$, $p<.05$). This interaction did not reach significance, however, when the degrees of freedom were adapted according to the Greenhouse and Geisser procedure (Winer, 1971) ($F_1(1,11)=2.4$, $p>.10$).

General discussion

Both Experiment 1 and Experiment 2 replicated the results of the Schvaneveldt et al. study, but failed to replicate the results of the Milberg et al. study, despite the fact that Experiment 2, in particular, closely paralleled the latter. In fact, the only important difference in the design of their study and Experiment 2 was that I controlled explicitly for possible repetition effects, whereas they apparently did not. Noι unexpectedly, the repetition effect is shown to be very strong when systematically examined. It seems therefore likely that the failure of the Milberg et al. study to find the same results as the Schvaneveldt et al. study and the experiments of this study may be attributable to the lack of an explicit control for repetition effects. It is therefore difficult to interpret the results for their normal control subjects with reference to the adopted psycholinguistic model (the selective access model).

This difficulty in interpreting the results for the normal control subjects does not invalidate the difference reported by Milberg et al. between the Broca and the Wernicke patients. The normal pattern of performance for the Wernicke patients and the absence of any priming effect for the Broca patients certainly are relevant findings, which are in need of further research and clarification. According to the logic of the two-step argument, however, the absence of data in support of the normal processing model adopted in the Milberg et al. study, excludes at present a fine-grained interpretation of their patient data in terms of such a model.

Postscript

In their reply to my note, Milberg and Blumstein (1989) give a number of arguments for their claim that "the minor differences between our data and those presented by Hagoort do not undermine our claims concerning semantic processing in different subgroups of aphasics, nor our comparison of these patients to normal subjects." (p. 349). As I will try to show, most of their arguments fail to address the points that I have raised above.

First of all, they state that a design in which all subjects are presented with every item in each condition (a full within-subject design) has more advantages than disadvantages in testing aphasic patients. Although they do not specify the advantages, one can think of reducing the problems caused by limitations in the availability of sufficient patients, by the greater between-subject variability, etc. My answer to this argument is straightforward. I fully agree. In doing group studies with aphasic patients, full within-subject designs are probably the only realistic option we have. The point I raised, however, is another one. Given that we have to use this type of design, we should be as careful as is possible in controlling for the possibly confounding effects of factors such as the repetition of targets and the use of strategies. In theory, Milberg and Blumstein seem to hold the same opinion when they state that "the effects of repetition per se can be minimized by maximally separating repeated targets within an experimental list, and by counterbalancing the effect of order of repetition and semantic priming." (p. 351). However, neither in their original study nor in their reply is it made explicit whether, and if so, how they actually did minimize the possibly confounding effects of repetition. So it remains unclear whether they did in practice what they advocate in theory.

Their additional argument that effects of repetition priming are shown to be independent of semantic priming effects, completely misses the point. That is not what is at stake. The issue is how one creates an experimental situation such that it validly measures the effects of semantic priming. To achieve this aim, the design should prevent the measures of this effect to be 'polluted' by the contribution of experimentally uncontrolled variables.

The authors further stress that the paradigm they used differed in a number of respects from that in the Schvaneveldt et al. (1976) study. This, they argue, makes it "unlikely that all possible comparisons would replicate exactly" (p. 350). One wonders as to what would make this unlikely. For what reason do certain comparisons replicate previous findings and why do other comparisons show a different result? It is likely that the answer to this question is not without theoretical implications. Milberg and Blumstein, however, do not seem to be bothered by this possibility. Neither do they comment on the fact that their results are in partial disagreement with three studies that, despite procedural differences, obtained identical patterns of results (Marcel in the unmasked version of his experiments, 1980; Schvaneveldt et al., 1976; my study). Most importantly, however, in Experiment 2 I have exactly replicated the results reported by Schvaneveldt et al. (1976) and Marcel (1980), using exactly the same paradigm as Milberg et al. (i.e., a within-subject design with repetition of targets, an auditory presentation, and an ISI of 500 msec). Should we thus conclude that it is also unlikely that all comparisons would replicate in studies with identical paradigms? The authors extensively comment on the procedural differences between their study and the one by Schvaneveldt et al., but do not give any explanation for the differences between their own results for the control group and those of my Experiment 2. Without further ado they simply state that these differences are trivial. Below I will argue that they are not.

Their final argument concerns the critical comparisons with respect to the issue of selective versus non-selective access. They argue, that what is most critical for choosing between both models, are the comparisons between, on the one hand, the discordant condition and the unrelated baseline, and, on the other hand, the discordant and the neutral condition. Milberg and Blumstein cite Schvaneveldt et al. in their claim that the concordant condition only served as a check for the reliability and validity of the procedure. Let me, for the moment, take this line of reasoning for granted. Schvaneveldt et al. concluded that this check was positive on the basis of the following results: "Responses to the third words of concordant associates were faster than responses to the third words of any other triple, thus supporting the reliability and validity of our general procedures."

(p. 250). Milberg et al. (1987), however, did not find reliably faster responses in the concordant condition relative to both the neutral and the discordant one. This, it seems to me, should make one worry about the reliability and validity of the procedures used by Milberg et al. They implicitly support this worry by the remark that because of "the relatively long ISIs used" in the experiment, it is impossible to conclude "that multiple meanings are not ever accessed in the course of word recognition" (p. 353). Finally, I am not acquainted with any model of selective access which does not also predict a reliable difference between the concordant and the discordant condition. In the absence of such a difference one should therefore be reluctant to take the results as support for a selective access model.

The reason for my debate with Milberg and his colleagues is not that I want to play the role of a stickler for methodological details, but it originates from what I think aphasiology should aim at. In my view, aphasiology is a branch of psycholinguistics in which we try to relate language processing deficits to models of normal language production and comprehension. In order to delineate the aphasic deficits in terms of a functional model of language processing, one should make sure that the results of the control groups confirm the predictions made from the normal model.

With the ultimate goal of aphasiology in mind, the conclusion by Milberg and Blumstein that the differences between their and my study have no implications for their claims concerning semantic processing in aphasic patients, is at the same time true and not true. It is true in the sense that my study does not invalidate their conclusion that the Wernicke's aphasics showed the same pattern of results as the normal control subjects, while the performance of the Broca's aphasics differed from that of both groups. It is not true, because a more detailed interpretation of the patient data in terms of a selective access model, or for that matter any other model of normal language processing, is difficult if not impossible in the absence of reliable data for the normal control subjects. This diminishes the chance of reaching the required level of interpretation for their otherwise interesting patient data. For this reason, minor differences may have major consequences.

3

TRACKING THE TIME COURSE OF MEANING SELECTION IN APHASIA: WORD CONTEXT EFFECTS

Accessing the mental lexicon and activating the information specified by its lexical entries, are central processes in both language production and language comprehension (Frauenfelder & Tyler, 1987; Levelt, 1989). These processes serve the purpose of providing the language processor with the information specified in the lexical entry of a word. One very important type of information contained in the lexicon is the meaning of words. Lexical meanings are the building blocks from which the sense of an utterance is constructed (Johnson-Laird, 1987). Lexical information is normally made available very rapidly, due in part presumably to the highly efficient internal organization of the mental lexicon. It is assumed that the lexicon is organized as a network of representational nodes that either increase or decrease their levels of activation via excitatory or inhibitory links with other nodes (e.g., McClelland & Rumelhart, 1981). At the lexical-semantic level of representation, the network is thought to be organized according to the degree of semantic similarity between the nodes. Nodes representing semantically related words are thought to be more strongly connected (i.e., via direct links) than nodes for unrelated words (Collins & Loftus, 1975).

In many aphasic patients lexical-semantic processing is severely disrupted. A number of studies (e.g., Goodglass & Baker, 1976; Whitehouse, Caramazza, & Zurif, 1978; Zurif, Caramazza, Myerson, & Galvin, 1974) has shown that especially Wernicke's aphasics show a deficit in activating the semantic information associated with lexical items. Zurif et al. (1974) presented aphasic and control subjects with triplets of words and required them to select the two that went best together. The words varied along semantic dimensions such as human-nonhuman, ferocious-harmless, etc. In contrast to the normal control subjects and the Broca's aphasics, the Wernicke patients were unable to group the words according to their shared semantic features. The studies by Goodglass and Baker (1976) and by Whitehouse et al. (1978) also required subjects to make explicit semantic judgements. These studies confirmed the findings of Zurif et al. in that for Wernicke's aphasics clear deficits in lexical-semantic processing were inferred from the results. The underlying deficit was thought to be a (partial) loss of the semantic information in the lexical entries or a disruption of the internal organization of the mental lexicon. Broca's aphasics, however, were claimed to have a more or less intact semantic lexicon (Zurif et al., 1974).

A number of recent studies (Blumstein, Milberg, & Shrier, 1982; Chenery, Ingram, & Murdoch, 1990; Katz, 1988; Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1987) casts serious doubts on this account of lexical-semantic deficits. These studies used a semantic priming paradigm with a lexical decision task. In this task subjects are required to decide whether a sequence of letters or sounds is a word or not. Decision times on word targets can be speeded up by a preceding word with an associative/semantic relation to the target word (Meyer & Schvaneveldt, 1971). Aphasic patients and control subjects were presented with prime-target pairs, or triplets (Milberg et al., 1987), consisting of words that were either associatively related or unrelated. Despite significantly longer response latencies, Wernicke's aphasics consistently showed the same pattern of results as the normal control subjects; that is, both the control subjects and the Wernicke patients needed less time to recognize the target as a word when it was preceded by an associatively related word. Surprisingly enough, the Broca's aphasics had a much less stable pattern of performance. In some studies they showed the expected priming effect (Blumstein, Milberg, & Shrier, 1982; Katz, 1988; Milberg, Blumstein, & Dworetzky, 1988), whereas in other studies this priming effect was absent (Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1987).

At least two conclusions can be drawn from these results. First, lexical-semantic deficits in aphasia are very often not due to a loss of "the integrity of the stored lexical knowledge base" (Milberg et al., 1987, p. 139), but to a problem in the access to or the operations on lexical-semantic information. This holds not only for lexical-semantic deficits in language comprehension, but also for those in language production (Le Dorze & Nespoulous, 1989).

Second, the way in which lexical-semantic information is used in tasks requiring explicit semantic judgements, might be different from the access of lexical-semantic information under implicit task conditions, which do not focus the subjects on the semantics of the presented words.[1] This difference between both types of tasks has been related (e.g., Milberg & Blumstein, 1981; Milberg et al., 1987) to the general dichotomy between automatic and controlled processing (Posner & Snyder, 1975; Shiffrin & Schneider, 1977). Automatic processes are fast, of short duration, do not require attention or awareness and do not draw from a common pool of processing resources. Controlled processing is slower, involves resource capacity, and is under the subject's intentional control, thereby allowing the subject's expectancies and strategies to play a role.

On the basis of the consistently reported semantic facilitation in lexical decision tasks, Milberg et al. (1987) claim that Wernicke's aphasics are able to automatically access word meanings, but are impaired in explicitly 'analyzing' the meaning of words. The latter skill presupposes that the lexicon can be accessed in a more controlled way. With some caution, the authors suggest the opposite pattern for Broca's aphasics. These patients are claimed to have little or no difficulty in controlled processing, but they do show an impairment in automatic access to lexical-semantic information. The claim for loss of automaticity in Broca's aphasia has also been made for other levels of language processing. Blumstein (1982) suggested that agrammatic comprehension might be caused by a loss of automaticity in accessing linguistic information at all levels of representation. Others have suggested a loss of the ability to automatically access a subset of lexical items, i.e. closed class words (e.g., Bradley, Garrett, & Zurif, 1980; Friederici, 1988b), or to automatically process syntactic information (Friederici & Kilborn, 1989).

Priming as an index of automatic processing

The claim for a dissociation between automatic and controlled lexical-semantic processing in both Broca's and Wernicke's aphasia is based upon a comparison of the results in two completely different tasks. The results in a lexical decision task are compared with the results in a set of tasks requiring the subject to make explicit semantic decisions. It is thereby assumed that the lexical decision task taps into the process of automatic access to lexical-semantic information. However, this assumption requires further qualification. There is convincing evidence (Balota & Chumbley, 1984; De Groot, 1984; De Groot, Thomassen, & Hudson, 1986; Keefe & Neely, 1990; Neely, 1977, 1990; Neely, Keefe, & Ross, 1989; Seidenberg, Waters, Sanders, & Langer, 1984) that priming effects can be attributed to a number of different mechanisms. Neely and Keefe (1989) argue that three different processes have to be assumed to account for the results in a large number of priming studies in which a lexical decision task has been used. Only one of these processes is claimed to be automatic, the remaining two are forms of controlled processing.

The first process is automatic spread of activation (ASA). Based on the assumption that a strong (or direct) link exists between semantically/ associatively related nodes in the lexical-semantic network, activation of a node that arises in response to the presentation of the corresponding word, spreads along the paths in the network to nodes representing words that are related in meaning. As a consequence, the activated nodes representing related word targets need less time for subsequent processing in a lexical decision or a naming task. However, the processing of unrelated words will be unaffected, since the activation levels of their nodes in the network will not have changed. ASA shows all the general characteristics attributed to automatic processes (see above). An additional important feature of ASA is that it is often assumed to only facilitate the processing of related targets, and not to inhibit the processing of unrelated target words (Neely, 1977; Posner & Snyder, 1975). ASA is especially effective when the stimulus-onset-asynchrony (SOA) between prime and target is short. Thus ASA contributes to priming effects only within a restricted temporal window. In priming studies using a visual presentation of primes and targets this temporal window ranges around an SOA of some 500 msec (De Groot, 1984; Neely, 1977; Prather & Swinney, 1989). After this short temporal window, automatic associative and semantic priming rapidly decreases.

A second mechanism that contributes to semantic priming effects is expectancy.[2] Subjects can generate an expectancy set on the basis of the information contained by the prime. This expectancy set consists of words that are potential targets. If the target is a member of this set, it will be recognized more quickly. If it is not, recognition will be slowed down. Unlike ASA, expectancy-induced priming therefore not only facilitates the processing of expected targets, but also inhibits the processing of unexpected targets (Neely, 1977). Posner and Snyder (1975) propose that this second priming mechanism is a form of controlled processing. As such expectancy-induced priming effects can be influenced by instruction and by the list structure of the materials (e.g., the proportion of related prime-target pairs). These factors can modulate the probability that subjects will generate an expectancy set of words related to the prime (Keefe & Neely, 1990). In contrast to ASA, expectancy is a rather slow process because it takes time to generate the expectancy set from the prime. This implies that expectancy-induced priming is only effective at longer SOAs between primes and targets.

The third mechanism in Neely and Keefe's (1989) hybrid three-process theory, is semantic matching. Semantic matching (or "post-lexical coherence checking" in the terminology of De Groot (1984)) operates in a lexical decision task, but cannot account for the priming results obtained with a naming task. In a lexical decision task subjects are assumed to match primes with targets and bias their decisions according to the results of this matching process. The detection of a relation between primes and targets leads to a bias for the "yes"-response. If no relation is detected, the "no"-response will be biased. Semantic matching results in facilitation for related target words. For unrelated target words, however, the semantic matching is without success, inducing a bias to respond with "no". As a consequence, the required "yes"-response for these target words will be inhibited. According to Humphreys (1985), the process of semantic matching takes some time, and therefore affects performance most when responses to targets are fairly slow. In contrast to expectancy, however, semantic matching can also be effective with relatively short SOAs between primes and targets (De Groot, 1984; but see Neely, 1990).

In sum, three different processes account for the results in priming studies using a lexical decision task. Of these processes, only automatic spread of activation is an automatic consequence of access to the prime's semantic node. Expectancy is a much slower, controlled process that gets triggered upon accessing the prime and can be influenced by instruction and by the list structure of the materials. ASA and expectancy both yield priming by speeding up the access to the lexical-semantic node that represents the target. In contrast to these two processes, semantic matching does not operate prior to target presentation. It is therefore a post-lexical process especially bound to the decision mechanism in binary choice tasks.

Because inhibitory effects that emerge in a lexical decision task can arise as a consequence of post-lexical (i.e., semantic matching) as well as pre-lexical (i.e., expectancy) processes, inhibition effects are not a waterproof empirical criterion for separating automatic and controlled access to lexical-semantic representations (Lorch, Balota, & Stamm, 1986). Moreover, dissociations have been reported between different defining features of automatic processes (see Logan, 1988). For example, preventing the intentional use of prime information (e.g., in situations where the prime is masked), does not necessarily preclude the occurrence of inhibition effects (see Humphreys, 1985). In conclusion, it is debatable whether the occurrence of inhibition is a reliable indicator of controlled access to lexical semantics. A more reliable way to separate the contributions of automatic and controlled lexical-semantic processing to priming effects in lexical decision studies, therefore, seems to be to vary the interval between primes and targets.

To date all priming studies with aphasic patients have used a fixed interval between primes and targets. The study by Milberg and Blumstein (1981) presented the stimuli visually with an SOA of 2000 msec between primes and targets. All the studies with an auditory stimulus presentation used an inter-stimulus-interval (ISI) of 500 msec (Blumstein et al., 1982; Chenery et al., 1990; Katz, 1988; Milberg et al., 1987, 1988). For the following two reasons the ISI in the auditory modality cannot be directly compared to delays between primes and targets in the visual modality. First, for the majority of polysyllabic words the recognition point for their spoken word forms precedes the end of the word (Marslen-Wilson, 1984, 1987). Second, semantic priming effects for spoken words have been obtained 150 msec after word onset, that is, well before the end of the word (Zwitserlood, 1989). This implies that the ISI of 500 msec underestimates the effective interval between primes and targets. Given the relatively long delays between primes and targets in all these priming studies with aphasic patients, one cannot safely conclude that they only or most strongly tapped automatic instead of controlled lexical-semantic processing. The dissociation between the priming results of Broca's and Wernicke's aphasics and their results in studies testing lexical-semantic processing with completely different tasks might also be explained in terms of task-specific factors. In conclusion, it is far from clear whether these different patterns of results obtained with completely different tasks can be explained in terms of impairments in either one of two separate access routines.

The present priming study with aphasic patients differs from all its predecessors in that three different intervals between primes and targets are used: a short, a medium, and a long one. This ISI manipulation serves the purpose of separating automatic and controlled lexical-semantic processing under exactly the same task conditions. In this way, a possibly differential pattern of results for short and long ISIs can no longer be attributed to differences in task aspects. Comparing the priming results obtained for aphasic patients at these three different ISIs, therefore, is a more straightforward test of the claims that Broca's and Wernicke's aphasics differ with respect to lexical-semantic processing in that the former are impaired in automatic and the latter in controlled access to lexical-semantic information. In this way the results allow firmer conclusions with respect to possible impairments in the underlying processing mechanisms.

The priming study showing the most marked difference between Broca's and Wernicke's aphasics is the one by Milberg et al. (1987). In this study, subjects were presented with two primes followed by a target. In three of the four priming conditions, the second prime was a homonym with two unrelated meanings. The relation of the first prime and the target with the two independent meanings of the homonym was manipulated in the different priming conditions. With some important modifications, the Milberg et al. study partly replicated the study by Schvaneveldt, Meyer and Becker (1976) in its design. The most remarkable result obtained by Milberg et al. was the significant interaction between the patient groups and the priming conditions. The Wernicke's aphasics showed the same priming effects as the normal control subjects, despite their significantly longer overall response times. The Broca's aphasics, however, did not show a significant priming effect. Milberg et al. suggest that processing deficits in Broca's aphasia (and in other patients with frontal lobe lesions) might be due to a general deficit in automatically processing stimulus contiguities. "As a result, they may fail to be influenced by the nature of the relation between contiguous elements. Presumably, the greater the number of elements to be related (in this case word triplets compared to word pairs), the more likely a deficit will emerge." (Milberg et al., 1987; pp. 147-148). This, then, should explain why Broca patients did show a priming effect in most studies using prime-target pairs (Blumstein et al., 1982; Katz, 1988; Milberg et al., 1988), whereas no priming effects were obtained when subjects were required to process three instead of two words.

In testing lexical-semantic processing deficits in aphasia, I therefore decided to extend and modify the Milberg et al. (1987) study in which the difference between Wernicke's and Broca's aphasics was found to be most marked.

Before discussing the experiments, some remarks have to be made on the processing of ambiguous words in the intact language processor.

The resolution of lexical ambiguity

One of the central issues in the extensive literature on the resolution of lexical ambiguity concerns the role of context in determining the appropriate reading of ambiguous words. In constructing the interpretation of an utterance, we are normally unaware of the inherent ambiguity of many of its ingredients. This in itself, however, does not imply that context guides lexical access such that only the contextually appropriate meaning of an ambiguous word is accessed. Quite the contrary: there is a fair amount of evidence that access to lexical meanings is not influenced by contextual information (Conrad, 1974; Lucas, 1987; Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). The process of accessing the meaning of words in a sentence seems to be informationally encapsulated from potentially relevant information in the sentential context (Fodor, 1983). The following general picture emerges from a number of recent studies on the resolution of lexical ambiguity (see Simpson, 1984).

When presented in isolation, all the meanings of an ambiguous word are activated (Holley-Wilcox & Blank, 1980). For ambiguous words with a dominant and a subordinate meaning, the activation of the dominant meaning builds up more rapidly than the activation of the less frequent meaning (Simpson & Burgess, 1985). Moreover, the less frequent meaning shows a faster decay (Burgess & Simpson, 1988; Simpson & Burgess, 1985).

The context can be used to modulate the activation of the different readings of an ambiguous word (Simpson, 1984). The nature of this modulation seems to depend on the type of context in which the ambiguous word is embedded. Minimally, a distinction should be made between a sentence context and a context consisting of words that are associatively/semantically related to a particular meaning of the ambiguous word. The latter type of context will be referred to as a priming context.

Studies on the resolution of lexical ambiguity in a sentence context have generally led to the claim that initially all meanings of an ambiguous word are accessed, independent of the contextual bias (Onifer & Swinney, 1981; Seidenberg et al., 1982; Swinney, 1979; Tanenhaus et al., 1979). After the initial access of the different meanings, the context very rapidly (i.e., within 200 msec) selects the appropriate one, while the inappropriate ones are suppressed (Seidenberg et al., 1982; for a more extensive discussion on the resolution of lexical ambiguity in a sentence context, see chapter 4).

The picture on the processing of ambiguous words in a priming context is more equivocal. In some studies selective activation of the biased meaning of ambiguous words has been reported (Schvaneveldt et al., 1976; Seidenberg et al., 1982). Other studies, however, report activation for both meanings of the ambiguous words (Marcel, 1980; Oden & Spira, 1983).

Schvaneveldt et al. (1976) presented triplets of letter strings (words and nonwords) to their subjects. For each letter string in the triplets subjects had to decide as quickly as possible whether it was a word or a nonword. In all the word triplets, the second word consisted of an ambiguous word with at least two independent meanings. In the concordant triplets, the first and the third word were related to the same reading of the ambiguous second word (e.g., *SAVE-BANK-MONEY*). In the discordant type the first and third word were related to different meanings of the ambiguous word (e.g., *RIVER-BANK-MONEY*). The neutral type started with a word that was unrelated to either reading of the ambiguous word, and, moreover, unrelated to the last word of the triplet (e.g., *DAY-BANK-MONEY*). In the so-called separated triplets only the first and the third words were associated (e.g., *SAVE-DATE-MONEY*). The overall baseline condition consisted of triplets with three unassociated words (e.g., *RIVER-DATE-MONEY*). The decision latencies for the triplet-final words were shortest in the concordant condition. The targets in the discordant condition, however, did not show any facilitation relative to the baseline of unrelated words. Intermediate facilitation for the triplet-final targets was obtained in the neutral and the separated conditions, in which two of the three words were associated. The authors interpret these results as support for a selective access model of the activation of lexical meanings. According to this model only the contextually appropriate meaning of ambiguous words gets accessed.

The results of the study by Schvaneveldt et al. are, however, open to an alternative interpretation. In their study, Schvaneveldt et al. asked subjects to do a lexical decision on every item of the visually presented triplets. After responding to the first item, the second appeared immediately and after the second the third item was immediately presented. This procedure resulted in an SOA between the members of the triplet of on average no less than 500 msec. Given this long interval between consecutive targets, the context effect could have been the result of the initial access to all meanings, followed by the rapid selection of the contextually appropriate one.

Balota and Duchek (1990) used (part of) the design from the Schvaneveldt et al. study in testing the processing of ambiguous words in elderly healthy adults and in Alzheimer patients. Balota and Duchek used a naming task, requiring their subjects to name each member of the triplet as quickly as possible. The pronunciation of the ambiguous word was followed by a delay of either 250 msec or 1250 msec before the target word appeared. The healthy elderly subjects replicated the results of the Schvaneveldt et al. study for both intervals, in that facilitation was obtained in the concordant but not in the discordant condition. The Alzheimer patients also showed a significant priming effect. However, these subjects differed from their controls in that they showed multiple instead of selective activation for the different meanings of ambiguous words.

Marcel (1980) also replicated the Schvaneveldt et al. study in its design and (partially) in its list of stimuli. He used ISIs of 600 msec and 1500 msec between the second (ambiguous) prime and the target. In Marcel's study subjects did not have to decide on the second prime. In one version of the experiment, the subjects were able to perceptually identify all members of the triplet, and the results supported the conclusion by Schvaneveldt et al., in that the context (i.e., the first member of the triplet) determined which meaning of the ambiguous word was activated. In another version of the experiment, Marcel presented the same triplets to his subjects, but with the ambiguous words pattern-masked. This prevented subjects from consciously perceiving them. In this masking condition, the results indicated the activation of both the contextually appropriate and the contextually inappropriate meaning of the ambiguous word. According to Marcel, accessing the meaning of a word precedes its perceptual identification. Initially all meanings of an ambiguous word are accessed. Prior context is only used after semantic access has taken place, to select the meaning that enters consciousness (Marcel, 1980).

Oden and Spira (1983) used a Stroop task to study the processing of ambiguous words in a priming context. They had subjects name the color of a target word, which followed the offset of an ambiguous word by 500 msec. In their semantic context condition the ambiguous word was preceded by two words strongly related to one of its meanings. In the biased-toward condition the colored target word was related to the same meaning as the two context words (e.g., *axle-wheel-tire-RUBBER*). In the biased-against condition, the target was related to a reading of the ambiguous word that did not match the one biased by the context (e.g., *axle-wheel-tire-SLEEPY*). Both the meaning biased by the word context and the non-biased meaning showed interference effects. This interference was largest for the contextually appropriate meaning. The 500 msec delay between the ambiguous words and the targets, however, might have given the context sufficient time to create this quantitative difference in interference between the biased and non-biased readings. At the time of probing, the context probably had already partially suppressed the contextually inappropriate meaning.

Seidenberg et al. (1982) used a cross-modal priming paradigm. Subjects were required to listen to sentences ending with an ambiguous word. After sentence offset a visual target word was presented with a delay of either 0 msec or 200 msec. Subjects had to name the target word as quickly as possible. In some of the experiments, the sentences contained a word that was semantically/associatively related to the contextually biased meaning of the homonym. If this word was related to a homonym which had two meanings belonging to the same grammatical form class (i.c. both were nouns), selective activation was obtained at both ISIs for the contextually biased meaning. If, however, both meanings of the homonym belonged to different form classes (i.c. one noun and one verb), activation of both meanings emerged at an ISI of 0 msec, while selective activation of the contextually biased meaning occurred at a delay of 200 msec. The authors attribute this difference between noun-noun and noun-verb ambiguities to a difference in the lexical representation of the two types of ambiguities. The different meanings of an ambiguous word are represented by separate semantic nodes. For noun-noun ambiguities the separate semantic nodes are linked to one form representation. The separate semantic nodes for noun-verb ambiguities, however, are assumed to be connected with separate form representations, one with the label noun, the other with the label verb (see Cottrell, 1988; Seidenberg et al., 1982; for arguments in favor of separate lexical entries for all lexically ambiguous words, see Kellas, Ferraro, & Simpson, 1988).

In sum, the results of a number of studies addressing the role of word contexts in the resolution of lexical ambiguity are open to different interpretations. The overall picture for the processing of ambiguous words in a priming context, however, seems to suggest that all meanings are initially accessed, with their levels of activation modulated by the context (Simpson, 1984).

In so far as the obtained priming effects in this type of context are due to the automatic spread of activation, the biased meaning of an ambiguous word increases its level of activation by receiving some of the activation from the prime's semantic node, resulting in a reduction of the latency to access this meaning of the ambiguous word upon encountering the associated word form. The latency to access the unbiased meaning, however, should be the same regardless of whether or not another meaning of the ambiguous word is primed. The automatic spread of activation leaves the non-biased meaning unaffected. Targets related to the biased as well as those related to the unbiased meaning will, therefore, show facilitation relative to an unrelated target. The largest facilitation, however, is obtained for the target related to the meaning that is primed by the word context.

A different pattern should emerge when priming is not only induced by automatic spread of activation. For instance, the suppression of the unbiased meaning is often assumed to be the result of some form of controlled processing. One proposal is that after the initial automatic access to all meanings of an ambiguous word, attention is allocated to the contextually appropriate one, with the inhibition of the inappropriate meaning(s) as the concomitant result (cf. Simpson, 1984).

In the remainder of this chapter I will use selective activation as a shorthand for rapid contextual selection of the appropriate meaning. It leaves open the possibility that initially all meanings are accessed following which the word context rapidly selects the appropriate one.

Introduction to the experiments

In the series of experiments to be reported, the processing of ambiguous words in aphasic patients is tested as a means to investigate the possible deficits of Broca's and Wernicke's aphasics in lexical-semantic processing.

In contrast to other priming studies with aphasic patients, the present study varies the ISI between the auditorily presented primes and targets. Three ISIs are used in separate experiments: 100 msec, 500 msec, and 1250 msec. The shortest ISI is expected to be within the temporal window of automatic lexical-semantic processing. The longest ISI is supposed to mainly tap more controlled lexical-semantic processing.

In addition to the variations in ISI, the type of ambiguity is explicitly manipulated. The stimuli consist of both noun-noun and noun-verb ambiguities. It has been suggested that the two types of ambiguity have a different lexical status, showing up as a difference in the pattern of results in studies using a priming context (Seidenberg et al., 1982). The representational difference between the two types of ambiguity is due to the fact that the two independent meanings of noun-verb ambiguities are associated with different grammatical form classes, while those of the noun-noun ambiguities share their form class representation. It is possible that especially Broca's aphasics show a deviant pattern of performance for these noun-verb ambiguities, which might be due to an impairment in the on-line exploitation of syntactic information associated with the different grammatical form classes (e.g., as encoded in inflectional affixes).

A final experiment manipulates the task aspects. In addition to the lexical decision task, subjects are given a task in which they are requested to judge the semantic relation between a subset of the words used in the priming experiments. In this way, the contribution of task aspects to the outcome of studies on lexical-semantic processing can be established with the same group of Broca's and Wernicke's aphasics.

Experiment 1

Experiment 1 was a replication of the Milberg et al. (1987) study with respect to its design and its ISI between the two prime words and the target. It differed, however, in three aspects from the experiment by Milberg et al. First, the materials were in Dutch. Second, the type of ambiguity was introduced as a separate factor. Third, repetition effects were explicitly controlled for (Hagoort 1989b; see previous chapter).

Method

Subjects

The subjects in this experiment were eighteen aphasic patients, and twelve elderly subjects from the subject pool of the Max Planck Institute for

Psycholinguistics. All subjects were right-handed. The elderly subjects were paid for their participation, and served as the normal control group. The normal controls were approximately matched with the aphasics patients in age and education. All aphasic patients were administered the Dutch version of the Aachen Aphasia Test (AAT) (Graetz, de Bleser, Willmes, & Heeschen, 1990; Huber, Poeck, Weniger, & Willmes, 1983; Huber, Poeck, & Willmes, 1984). Patients were diagnosed by aphasia type both on the basis of their AAT-results and on the basis of a transcribed sample of their spontaneous speech. The characteristics of the spontaneous speech were judged by three staff members of the Aphasia Project at the Max Planck Institute. Twelve patients were unanimously diagnosed as Broca's aphasics, and five received the unanimous diagnosis of Wernicke's aphasia. One patient was diagnosed as anomic. All aphasic subjects had a cerebral vascular accident (CVA) in the left hemisphere. For ten of the twelve Broca's aphasics the onset of their aphasia preceded the time of testing by two years or more. For two patients the interval between onset of aphasia and time of testing was about a year. Four Wernicke's aphasics and the anomic aphasic had an aphasia for more than two years when testing began. One Wernicke patient was tested four months after time of onset. Table 1 shows a summary of the patients' age, gender, scores on the Token Test, and their performance on the AAT-subtest on comprehension. The mean age for the normal control subjects was 57.5 years (range: 51-65), the mean age for the Broca patients was 54.1 years, and the mean age for the Wernicke patients was 67.6 years.

Materials

The stimuli consisted of auditorily presented triplets of sound sequences, the first two of which were real Dutch words serving as the primes. The third one served as the target. The target could be either a word or a nonword. In three of the four priming conditions for real word targets, the second prime was a word with two or more unrelated meanings. These ambiguous primes were taken from an extensively pretested list of Dutch words with two or more independent meanings (Hagoort 1989b; see chapter 2). Sixteen noun-noun ambiguities, 15 noun-verb ambiguities, and 1 adjective-verb ambiguity were selected, all with a relatively strong associate for both meanings. Half of the noun-noun ambiguities had equibiased meanings. The other half consisted of ambiguous words with a dominant and a subordinate reading. The set of noun-verb ambiguities consisted of six items with two equibiased readings and ten with a dominant and a subordinate reading.

As in the Milberg et al. (1987) study, there were four priming conditions for the word targets. Table 2 gives examples of the materials in the four priming conditions and in the two ambiguity types. In the

TABLE 1

Patient information

Patient	Age	Sex	Token Test**	Comprehension*** Score AAT	Audit. Compr. Score AAT
01 Broca	58	m	2	104/120	48/60
02 Broca	62	m	24	76/120	42/60
03 Broca	54	f	30	93/120	51/60
04 Broca	54	m	37	73/120	43/60
05 Broca	59	f	9	98/120	47/60
06 Broca	60	m	21	102/120	51/60
07 Broca	23	m	34	100/120	54/60
08 Broca (*)	33	f	31	85/120	49/60
09 Broca (*)	74	m	11	97/120	46/60
10 Broca (*)	48	m	42	86/120	39/60
11 Broca (*)	56	m	33	99/120	45/60
12 Broca (*)	68	f	20	90/120	43/60
13 Wernicke	72	m	24	59/120	41/60
14 Wernicke	76	m	32	83/120	31/60
15 Wernicke	70	m	43	77/120	35/60
16 Wernicke	64	m	19	82/120	36/60
17 Wernicke (*)	56	m	42	90/120	46/60
18 Anomic (*)	52	m	39	82/120	36/60

* The patients marked with an asterisk only participated in Experiment 1. All other patients also participated in the Experiments 2, 3, and 4.

** Scores on the Token Test are corrected for age. Severity of the disorder as indicated by the Token Test: no disorder (0-3); light (4-10); middle (11-33); severe (>33).

*** Severity of the comprehension disorder as indicated by the AAT subtest Comprehension (includes word and sentence comprehension in both auditory and visual modality): severe (0-59); middle (60-89); light (90-104); no disorder (105-120).

Ranges of severity are based on the norms for the German version of the AAT.

concordant condition, the first prime and the target were related to the same meaning of the second (ambiguous) prime. In the *discordant* condition, the first prime and the target word were related to alternative meanings of the second prime. In the *neutral* condition, the first prime was unrelated to both second prime and target, but the target word was related to one meaning of the ambiguous word. Finally, in the *unrelated* condition, the three words were unrelated and unambiguous. For the complete set of

TABLE 2

Examples of the prime and target words in each condition. Target words are in capitals.

Priming Condition	Prime 1	Prime 2	Target Word	
		Type of Ambiguity: Noun-Noun		
Concordant:	*bier*	*kater*	*DRANK*	(beer-tomcat/hangover-DRINK)
Discordant:	*poes*	*kater*	*DRANK*	(cat-tomcat/hangover-DRINK)
Neutral:	*piano*	*kater*	*DRANK*	(piano-tomcat/hangover-DRINK)
Unrelated:	*poes*	*piano*	*DRANK*	(cat-piano-DRINK)
		Type of Ambiguity: Noun-Verb		
Concordant:	*priesters*	*missen*	*KERK*	(priests-masses/miss-CHURCH)
Discordant:	*heimwee*	*missen*	*KERK*	(homesickness-masses/miss-CHURCH)
Neutral:	*maaltijd*	*missen*	*KERK*	(meal-masses/miss-CHURCH)
Unrelated:	*heimwee*	*maaltijd*	*KERK*	(homesickness-meal-CHURCH)

materials, see Appendix 1.

The dominant and the subordinate meanings of the non-equibiased ambiguities were equally represented by the set of target words. In this way a systematic bias of meaning dominance in either the concordant or the discordant condition was avoided. For the set of noun-verb ambiguities both readings were equally represented by the targets. For eight items, the target was related to the verb-reading. The remaining targets were related to the noun-reading.

The test stimuli were arranged in two blocks. The first block contained the four priming conditions for the 16 Noun-Noun triplets. The second block contained all the priming conditions for the 16 Noun-Verb triplets (including 1 Adjective-Verb triplet). In addition to the 64 word triplets, each block consisted of 32 triplets in which the target was a pronounceable nonword. In half of these nonword triplets, the first two words were unrelated and unambiguous (e.g., *vogel-drank-GLEM*; "bird-drink-GLEM"); in the other half, the first word was ambiguous and the second word was related to one of its meanings (e.g., *kater-drank-WELM*; "tomcat/hangover-drink-WELM"). Each nonword triplet appeared twice in the experimental session. In this way, the materials were constructed in exactly the same way as in the Milberg et al. study. The order of the four priming conditions was counterbalanced among the word triplets. This was done by taking two random samples of 16 from the 24 possible condition orders, one for the block of Noun-Noun items, and one for the block of Noun-Verb items. These 16 orders were randomly assigned to the 16 critical word items per block. In this way, potentially confounding repetition effects of the four target word presentations could be controlled for. In addition, two instances of the same target word were separated by at least five other trials.

The full experiment thus had 256 experimental triplets, presented in two blocks of 128. Each block was preceded by 12 startup items. The experimental session began with a set of 20 practice items to familiarize the subjects with the task.

All materials were spoken by a female speaker in a sound-proof booth and recorded on a Revox A 700 tape recorder. The stimuli were digitized and stored in a VAX 750 computer with a sampling rate of 20 kHz. A speech wave form editing system was used to construct the triplets from the single words and nonwords. Identical words were represented by the same physical token. A trigger pulse was placed concurrent with the onset of each target. The silent interval (ISI) between the members of a triplet was 500 msec. There was a 4-sec silent interval between the triplets. Two test tapes were constructed, one with the Noun-Noun items, the other with the Noun-Verb items. In addition, a tape was made containing the set of practice items. The input to and the output from the computer were low-pass filtered with a cutoff frequency of 10 kHz.

Apparatus

The apparatus for the experiment consisted of a Revox B77 stereo tape recorder, a Miro GD laboratory computer, a pulse-read unit, two pairs of Sennheiser HD 224 closed headphones (one for the subject and another for the experimenter), and a response keyboard with a YES button on the left side and a NO button on the right side. The test stimuli on the left channel of the tape were played binaurally to the subject, while the trigger pulses on the right channel of the tape started a millisecond timer. The pulses were inaudible to the subjects. Reaction times and type of response (yes/no) were stored directly with the aid of the computer. The time-out was set to 5 seconds. Latencies longer than 5 seconds were automatically stored as missing values.

Procedure

The subjects were tested individually in a single session, lasting approximately 60 minutes including a break of 10 minutes after the first block. Subjects were seated in a quiet room diagonally opposite the experimenter, with the keyboard placed in front of them.

Subjects were told that they would hear a series of triplets either ending with a real Dutch word or ending with a nonword. They were instructed to respond to the third member of the triplet as quickly as possible, indicating whether it was a word by pressing the YES button, or a nonword by pressing the NO button. For some patients the series of practice items had to be repeated to make sure that they understood the task. After the familiarization procedure, the subjects were asked to increase the speed of responding without losing accuracy. The emphasis on speed served the purpose of making the task as on-line as possible. No further feedback was given during the test session.

Due to the occurrence of hemiparesis or hemiplegia in a number of patients, all patients were required to respond with their left index finger. Patients were instructed to place their left index finger on the YES button and to move their finger to the NO button if they wanted to give a no-response. This was done to speed up the reaction times for the more important yes-responses and to avoid an increase in the error variance as a result of movements to be made from a starting position between the two buttons. To validate this procedure, half of the normal control subjects were required to react according to the same procedure, the other half of the subjects were required to respond with the left index finger on the YES button and with the right index finger on the NO button.

At the end of the test session the experimenter interviewed the subjects about the salient features of the stimuli. This was done to find out whether subjects were aware of the presence of the ambiguous words.

Results

The results for the normal control subjects and the aphasic patients were analysed separately. For the RT-data, statistical analyses were based on the subjects' median latencies in each condition. For groups of aphasic patients, the distribution of the RT-data has a tendency to show a skewness to the right. In comparison with the sample means, the sample medians are, therefore, better estimators of the population means.[3] For the analyses on RT-data, errors and missing values were replaced for every subject by his/her median per condition.

Only subject analyses will be reported, for two reasons. First, because of the variability between patients, generalizations to aphasic syndromes are critically dependent on the results of the subject analyses. Second, the repetition effects caused by repeating target words four times form an improper source of error variance in the item analyses. For the interpretation of the results, the subject analyses are, therefore, most decisive. In all cases, Repeated Measures Analyses of Variance were performed, in which Subjects, Priming Condition with four levels (concordant, discordant, neutral, unrelated), and Type of Ambiguity with two levels (noun-noun ambiguity, noun-verb ambiguity) were completely crossed. Analyses of the latency data were performed on the subject medians for each condition. Analyses of the error data were done on the mean number of errors per subject by condition. Unless explicitly stated otherwise, post-hoc comparisons used the Newman-Keuls procedure with a significance level of 0.5 (Winer, 1971).

Latency analyses

The results for the normal control subjects and both patient groups are summarized in Table 3. To validate the response procedure, an analysis of variance (ANOVA) was first done on the RT-data of the normal controls with Response Procedure as additional factor. Six subjects reacted with the left index finger, and six subjects used both index fingers. Most critical are the interactions of Response Procedure with Type of Ambiguity and with Priming Condition. None of these interactions approached significance (Response Procedure by Type of Ambiguity: $F<1$; Response Procedure by Priming Condition: $F(3,30)=1.72$, $MSe=903$ $p=.18$). The main effect of Response Procedure was not significant either ($F(1,10)=3.29$, $MSe=39071$, $p=.10$). These results indicate that both response procedures were equally sensitive to the experimental manipulations. For further analyses, data were collapsed across response procedures.

The ANOVA on the latency data of the normal control subjects yielded a significant main effect of Type of Ambiguity ($F(1,11)=15.44$, $MSe=2611$, $p<.005$). Latencies to noun-noun targets were on average 46 msec shorter than those to noun-verb targets. Recall that different target words were used in the sets of noun-noun and noun-verb items. The main effect for Type of Ambiguity was mainly due to a difference in duration between the spoken noun-noun and noun-verb word targets. Although the mean number of syllables (1.75) and the mean number of letters (5.6) was equal for the sets of noun-noun and noun-verb targets, the spoken word-forms for both target types had on average a durational difference of 56 msec. The mean length of the noun-noun targets was 563 msec (range: 360-691), while the noun-verb targets had a mean length of 619 msec (range: 484-856). In a replication of the experiment using a visual presentation, the difference between noun-noun and noun-verb targets was no longer significant (Latencies were 439 msec for the noun-noun targets and 448 msec for the noun-verb targets). The main effect of Type of Ambiguity is, therefore, trivial.

The ANOVA also yielded a significant main effect of Priming

TABLE 3

Means (both across and by Type of Ambiguity) of the median auditory lexical decision times as a function of Priming Condition (ISI=500 msec).

ISI=500 msec	Overall		Noun-Noun		Noun-Verb	
Priming Condition	RT	d	RT	d	RT	d
	Normal Controls (N=12)					
Concordant	717	54	697	59	736	49
Discordant	751	20	713	43	789	–4
Neutral	739	32	729	27	750	35
Unrelated	771		756		785	
	Broca's Aphasics (N=12)					
Concordant	740	35	700	59	780	10
Discordant	768	7	722	37	815	–25
Neutral	741	34	710	49	771	19
Unrelated	775		759		790	
	Wernicke's Aphasics (N=5)					
Concordant	856	80	839	56	874	103
Discordant	938	–2	897	–2	980	–3
Neutral	923	13	871	24	976	1
Unrelated	936		895		977	

Differences (d) are measured relative to the unrelated baseline.

Condition ($F(3,33)=12.57$, $MSe=963$, $p<.0001$). In addition, a significant interaction emerged between Type of Ambiguity and Priming Condition ($F(3,33)=6.37$, $MSe=557$, $p<.005$). Inspection of Table 3 reveals that this interaction was due to the different results in the discordant priming condition for both ambiguity types. Separate analyses of variance for the two types of ambiguity showed that simple main effects of Priming Condition were significant for noun-noun ambiguities ($F(3,33)=8.05$, MSe=946, $p<.0005$), as well as for noun-verb ambiguities ($F(3,33)=13.99$, MSe=574, $p<.0001$).

Separately testing the differences between the priming conditions for both types of ambiguity by means of Newman-Keuls tests, revealed that the noun-noun items had shorter latencies in the concordant condition relative to the neutral condition and the unrelated baseline. In addition, the neutral and the discordant condition resulted in faster reaction times than the unrelated baseline. However, there was no significant difference between the concordant and the discordant condition.

For the noun-verb items, the post-hoc test indicated that the concordant and the neutral priming condition showed facilitation relative to both the discordant condition and the unrelated baseline. The latter two priming conditions did not differ from each other.

In summary, normal control subjects showed facilitation for both types of ambiguity in the concordant and the neutral priming condition relative to the baseline. Facilitation in the discordant condition was obtained for the noun-noun items, but not for the noun-verb items.

Analyses of variance on the patient data included only the Broca's and Wernicke's aphasics.[4] An ANOVA with Group of Patients as additional factor, revealed a significant main effect for Group of Patients ($F(1,15)=4.63$, MSe=151401, $p<.05$). The Broca's aphasics responded significantly faster than the Wernicke's aphasics. However, none of the interactions with the factor Group of Patients was significant. Most importantly, neither the interaction between Group of Patients and Priming Condition ($F(1,45)=2.17$, MSe=2717, $p=.11$), nor the Patient Group by Type of Ambiguity by Priming Condition interaction ($F(3,45)=1.37$, MSe=2677, $p=.27$) approached significance. Before analyzing the data of both patient groups separately, a first analysis was, therefore, done on the pooled group data.[5]

Significant main effects were obtained in this analysis for Type of Ambiguity ($F(1,16)=13.75$, MSe=11838, $p<.005$), and Priming Condition ($F(3,48)=5.82$, MSe=2915, $p<.005$). The interaction between Type of Ambiguity and Priming Condition, however, failed to reach significance ($F(3,48)=1.01$, MSe=2738, $p=.39$).

The overall differences between the four priming conditions were tested in a Newman-Keuls post-hoc test, which showed facilitation for the concordant condition relative to both the discordant priming condition and the unrelated baseline. Latencies in the latter two conditions did not differ from each other.

The significant overall priming effect was confirmed in separate ANOVAs for the two patient groups, which yielded a significant main effect of Priming Condition for both the Broca's ($F(3,33)=3.68$, MSe=2166,

$p<.05$), and the Wernicke's aphasics ($F(3,12)=3.52$, $MSe=4234$, $p<.05$). The interaction between Type of Ambiguity and Priming Condition did not attain significance for the Wernicke patients ($F<1$), but was marginally significant for the Broca patients ($F(3,33)=2.59$, $MSe=1650$, $p=.069$).

A Newman-Keuls test comparing the overall means for the Wernicke's aphasics in the different priming conditions, showed that latencies in the concordant condition were significantly faster than those in all the other conditions, which did not differ among each other.

Because of the marginally significant interaction between Type of Ambiguity and Priming Condition, the results of the Broca's aphasics were submitted to separate analyses for the noun-noun and the noun-verb items. The effect of Priming Condition was shown to be significant for both types of ambiguity (for noun-noun items: $F(3,33)=3.37$, $MSe=2362$, $p<.05$; for noun-verb items: $F(3,33)=2.94$, $MSe=1454$, $p<.05$). A post-hoc Newman-Keuls test revealed that the difference between the concordant and the discordant condition was not significant for the noun-noun items. However, the concordant and the neutral condition showed facilitation relative to the baseline, and so did the discordant condition in a Duncan test ($p<.05$). For the noun-verb ambiguities, the difference between the concordant and the discordant condition just failed to reach significance with a Newman-Keuls test, but was significant when a Duncan test was used ($p<.05$). However, a reliable facilitation of the concordant condition relative to the unrelated baseline was not obtained.

In summary, both patient groups showed significant overall priming effects, with the largest amount of facilitation in the concordant priming condition, while no overall facilitation was obtained in the discordant priming condition. Especially the Broca's aphasics showed, at least for the noun-noun ambiguities, a similar pattern of results as the control subjects. That is, both readings of the noun-noun ambiguities were activated. The absence of differential activation for the concordant and the discordant condition implies that no contextual selection of the appropriate noun reading has been taken place. In contrast, for the noun-verb ambiguities all subject groups had shorter latencies in the concordant than in the discordant condition, indicating a contextual selection effect for this type of ambiguity. The Wernicke's aphasics differed from the other two groups of subjects in that no multiple activation could be established for the noun-noun ambiguities.

Error analyses

Table 4 summarizes the error data for both normal control subjects and patient groups. The normal control subjects made errors on less than 1% of the critical word target trials. An analysis of the error data showed that none of the main effects nor any of the interactions approached significance.

To further validate the response procedure for the aphasic patients, an ANOVA was done on the error scores of the normal control subjects, with Response Procedure as an additional factor. The overall error percentage of the subjects responding with both index fingers was 1.2%. The subjects using their left index finger only, had an overall error score of 0.5%. This difference did not approach significance ($F<1$). More importantly, the interactions of Response Procedure with Type of Ambiguity ($F<1$), and with Priming Condition ($F<1$) also failed to reach significance. Given that the response procedures had no differential effect on either the latency data or the error data, it can be safely inferred that the particular response procedure used with the aphasic patients had no differential influence on their pattern of results.

The group of Broca's aphasics made errors on 2.1% of the word targets. The group of Wernicke patients had an error score of 7.7%. In an analysis of variance including Group of Patients as an additional factor, this difference was shown to be significant ($F(1,15)=4.77$, $MSe=0.0179$, $p<.05$). Significant main effects were also obtained for Type of Ambiguity ($F(1,15)=6.03$, $MSe=0.0025$, $p<.05$), and for Priming Condition ($F(3,45)=3.55$, $MSe=0.0014$, $p<.05$). However, a significant interaction arose between Group of Patients and Priming Condition ($F(3,45)=2.80$, $MSe=0.0014$, $p=.05$). Therefore, separate analyses were done on the error scores of both patient groups.

The analysis on the error data of the Broca's aphasics only yielded a significant effect for Type of Ambiguity ($F(1,11)=5.43$, $MSe=0.0027$, $p<.05$). Neither the effect of Priming Condition, nor the interaction between Type of Ambiguity and Priming Condition approached significance (both $Fs<1$).

For the group of Wernicke patients no significant main effects emerged for Type of Ambiguity ($F(1,4)=2.28$, $MSe=0.0021$, $p=.21$) or for Priming Condition ($F(3,12)=2.09$, $MSe=0.0029$, $p=.16$). The interaction between Type of Ambiguity and Priming Condition was also not significant ($F<1$).

In sum, the analyses on the error data of the normal controls and both patient groups do not further qualify the effects that were obtained for their respective latency data. No evidence was found for the presence of a speed-accuracy trade-off.

TABLE 4

Mean percentage of errors (both across and by Type of Ambiguity) as a function of Priming Condition (ISI=500 msec).

ISI=500 msec	Overall	Noun-Noun	Noun-Verb
Priming Condition			
	Normal Controls (N=12)		
Concordant	1.3	1.0	1.6
Discordant	0.5	0.0	1.0
Neutral	1.0	0.5	1.6
Unrelated	0.5	1.0	0.0
	Broca's Aphasics (N=12)		
Concordant	1.8	1.0	2.6
Discordant	2.1	0.5	3.6
Neutral	2.1	1.0	3.1
Unrelated	2.6	1.0	4.2
	Wernicke's Aphasics (N=5)		
Concordant	5.6	5.0	6.3
Discordant	10.6	7.5	13.8
Neutral	5.6	6.3	5.0
Unrelated	8.7	7.5	10.0

Introspective report

At the end of the test session subjects were interviewed about the experimental materials. All control subjects and all patients noted that target words were repeated. Eight control subject remarked that the words in the triplets were sometimes semantically related. Seven Broca's aphasics and two Wernicke's aphasics also noted the occurrence of meaning relations between some of the words. Only two control subjects, and none of the patients, were aware of the fact that a subset of the materials consisted of words with different readings.

Discussion

For the normal control subjects the results of the concordant, the neutral and the unrelated conditions are in agreement with the patterns of performance reported by Schvaneveldt et al. (1976), by Marcel (1980), and by Hagoort (1989b; see previous chapter). The strongest priming effects are obtained for the concordant condition, where both the first and the second prime is related to the target. In this case facilitation results from the combined effect of the relatedness of both primes with each other and with the target. A lesser, but still significant amount of facilitation is seen in the neutral priming condition, in which neither meaning of the ambiguous words is biased. Priming in this condition is obtained solely by virtue of the relationship between the target and the meaning of the ambiguous word that it relates to. Both multiple access to the different meanings of an ambiguous word, and selective access to the target-related meaning for some ambiguities and to the target-unrelated meaning for others would result in this intermediate priming effect. In the latter case, the variances in the RTs for the neutral triplets should be higher than for the other triplet types. An F-max test on the variances showed that the variance of the RTs in the neutral condition did not differ from the variances in the other conditions.[6] This suggests that in the neutral context, both meanings of the ambiguous words were accessed.

Quite unexpected, however, are the results for the discordant condition. These indicate a clear difference between the noun-noun and the noun-verb ambiguities. Whereas for the noun-verb ambiguities selective activation of the contextually appropriate meaning occurs, in the case of the noun-noun ambiguities multiple activation of both the contextually biased and the non-biased meaning is obtained. This is surprising because a group of younger subjects (students) tested with the same materials did not show this multiple activation effect (see Table 5). For younger subjects, both in a design presenting primes and targets only once to the subjects, and in the design which was also used in this study, the noun-noun ambiguities as well as the noun-verb ambiguities showed selective activation of the contextually appropriate meaning. The picture emerging for the elderly subjects, however, seems to suggest that a biasing word context does not result in the selection of the contextually appropriate meaning of ambiguous words if both meanings belong to the same grammatical form class. After the initial access to both noun-meanings, the word context information does not seem to allow the elderly subjects to rapidly suppress the inappropriate meaning. This pattern of results is similar to that obtained by Balota and Duchek (1990) for their Alzheimer patients. However, if the two meanings differ in their form class, the context is effective in selectively activating the appropriate one. That is, the word context is used to rapidly suppress the inappropriate reading of an ambiguous word.

TABLE 5

Means (by Type of Ambiguity) of the median auditory lexical decision times as a function of Priming Condition (ISI=500 msec).

ISI=500 msec	Noun-Noun		Noun-Verb	
Priming Condition	RT	d	RT	d
Students in the design without repetition of the materials (N=40)				
Concordant	567	80	673	62
Discordant	638	9	727	8
Neutral	620	27	709	26
Unrelated	647		735	
Students in the design with repetition of the materials (N=12)				
Concordant	567	59	624	47
Discordant	620	6	691	–20
Neutral	588	38	656	15
Unrelated	626		671	

Differences (d) are measured relative to the unrelated baseline.

One way to explain the unexpected multiple activation for noun-noun ambiguities is by referring to strategies invoked by the subjects. The repetition of ambiguous words and targets in different priming conditions might have induced the strategy of not selecting the reading that fits the word context made up by the first prime. This explanation, however, is unlikely for the following reasons. First, it is not clear why only elderly subjects use such a strategy. Second, it does not explain why such a strategy is used with noun-noun ambiguities, but not with noun-verb ambiguities. Third, the majority of the subjects was unaware of the multiple meaning character for a subset of the words.

A more likely explanation for the obtained difference between the two types of ambiguity is related to the difference in their representational make-up. Whereas noun-noun ambiguities only differ at the level of lexical-semantic representations, noun-verb ambiguities have an additional difference in their syntactic features. The presupposed locus of this difference is either at the level of form representations (Seidenberg et al., 1982), or at a separate level of representation specifying the grammatical form class associated with each meaning (Cottrell, 1988). Whatever the ultimate representational locus of the additional form class difference turns out to be, it might have provided the context with an extra source of information to effectuate the suppression of the contextually inappropriate reading. The contribution of form class in this regard does not necessarily require direct form class priming to occur.[7] Even if the word context does not directly bias the contextually appropriate form class, but only the contextually appropriate semantic representation of the ambiguity, this spread of activation to the contextually appropriate meaning might increase the activation of the associated form class representation via the link between both types of representation. In this indirect way, the appropriate form class representation also increases its level of activation. Upon the presentation of a noun-verb ambiguity, therefore, both the form class representation and the meaning representation of the contextually appropriate reading have increased their levels of activation. For noun-verb ambiguities, two levels of representation can thus contribute to the selection of the contextually appropriate meaning, by allocating attention to both the appropriate meaning and the appropriate form class. In contrast to the younger, highly educated subjects, the older and less well-educated subjects seem to need the additional source of information contained in the lexical entries of the noun-verb ambiguities to allow a word context to do its work in selecting the appropriate and suppressing the inappropriate reading.

The results of the aphasic patients clearly differ from those in the Milberg et al. (1987) study. In contrast to Milberg et al., I failed to find an interaction between priming context and patient group. Not only Wernicke's aphasics, but also Broca's aphasics showed significant priming effects. The Broca's aphasics showed the same tendency for the two types of ambiguities as the normal control subjects. Differential effects for the contextually appropriate and the contextually inappropriate reading were absent for the noun-noun ambiguities, but did emerge for the noun-verb ambiguities. This indicates that as was the case for the normal controls, contextual selection was absent in the set of noun-noun ambiguities, while it was marginally effective in the set of noun-verb ambiguities.

In accordance with the results for the other two subject groups, the Wernicke patients had the shortest latencies in the concordant condition, indicating that the lexical context information could be used to activate the contextually appropriate meaning of the ambiguity. In contrast to the other subjects, the Wernicke patients showed no evidence of multiple activation for noun-noun ambiguities.

Two aspects of the results of the aphasic patients deserve separate mention. First, again a clear semantic (associative) priming effect is established for a group of Wernicke patients. Together with the semantic priming effects obtained for Wernicke patients in a number of previous studies (Blumstein et al, 1982; Milberg & Blumstein, 1981; Milberg et al., 1987, 1988), this result supports the claim that the lexical-semantic deficits typically found in Wernicke's aphasia (Goodglass & Baker, 1976; Whitehouse et al., 1978; Zurif et al., 1974) are not so much due to a structural impairment of the lexical-semantic network, but rather to the inability to operate on lexical-semantic information after it has been automatically accessed.

Second, the discrepancy between the results of the Broca patients reported by Milberg et al. (1987) and those obtained in this study needs to be clarified. In contrast to the present study, Milberg et al. did not obtain a significant overall priming effect. In fact, the Broca patients in their study showed the longest latencies in the concordant and the shortest latencies in the discordant condition. Milberg et al. (1987) suggest that the absence of a priming effect for their Broca's aphasics might indicate a deficit in the automatic access to lexical-semantic information. If this explanation is correct, one way to explain the different outcomes of both studies is by assuming that in Broca's aphasics the degree of severity of their aphasia is correlated with the degree of impairment in automatically accessing lexical-semantic information. Possibly the Broca's aphasics in the Milberg et al. study differ in the degree of severity from the patients in my study, with the latter ones having a less severe aphasia. One piece of evidence supporting this suggestion is the difference in the overall latencies of the patients' responses in both studies. The Broca's aphasics in this study were much faster (on average 650 msec) than the Broca patients in the Milberg et al. study. Even taking into account that the response procedure and the request for speed in the instruction of Experiment 1 contributed to the relatively fast responses, the remaining difference in the response latencies is still substantial.[8] In as far as this latency difference indicates a difference in the degree of severity between the groups of Broca patients in both studies, it might be the case that with an ISI of 500 msec the deficit in the automatic processing of ambiguous words reveals itself only in the most severely impaired group of patients. This implies that a possible deficit in the automatic processing of lexical-semantic information is expected to show up in the relatively less impaired group if the task conditions tap the automatic spread of activation more strongly than in Experiment 1.

Experiment 2

One way to increase the contribution of ASA to the priming effects is by reducing the ISI between the members of the triplets. Therefore, I decided to do a second experiment with the same materials and the same patients, but with the ISI reduced to 100 msec. Aphasic patients with an impairment in the automatic access of lexical-semantic information are expected to show no, or at least reduced priming effects with an ISI of 100 msec.

Method

Subjects
A group of twelve elderly right-handed subjects from the MPI subject pool served as the normal controls. None of these subjects had participated in Experiment 1. The control subjects were matched in age and education with the aphasic patients. The mean age for the group of normal control subjects was 59.8 years (range: 46-72). A group of eleven aphasic patients participated in this experiment. Seven patients were diagnosed as Broca's aphasics, four patients as Wernicke's aphasics. The Broca's aphasics had a mean age of 52.8 years, the Wernicke's aphasics had a mean age of 70.5 years. This group of eleven patients also participated in Experiment 1 (see Table 1). Seven of the patients participating in Experiment 1 were no longer available. The time interval between the test sessions of Experiment 1 and Experiment 2 was at least four months.

Materials
The same digitized tokens as in Experiment 1 were used to construct two new test tapes and a new practice tape. The only difference with the tapes of Experiment 1 was the interval of silence between the members of a triplet. With the help of a speech waveform editing system, the ISI was reduced to 100 msec. There was a 4-sec interval of silence between the triplets. The output from the computer was low-pass filtered with a cutoff frequency of 10 kHz.

Apparatus
The apparatus used in Experiment 2 was identical to the apparatus used in Experiment 1.

Procedure
The procedure was the same as in Experiment 1, with one minor change. In Experiment 1, it was demonstrated that responding with one or two

fingers made no difference for the results on the word targets. Therefore, in Experiment 2 the normal control subjects and the patients with complete control of both hands were instructed to place their left index finger on the YES button and their right index finger on the NO button. Aphasic patients with control of their left hand only were required to place their left index finger on the YES button. They were instructed to press the YES button as quickly as possible if they heard a word, and to move their finger to the NO button and press it if they heard a nonword.

Results

The replacement of errors and missing values, and the analyses of the results were done in the same way as in Experiment 1. Table 6 summarizes the results for the normal controls, the Broca's aphasics, and the Wernicke's aphasics.

Latency analyses

The ANOVA on the latency data of the control subjects yielded significant effects of Type of Ambiguity ($F(1,11)=83.98$, $MSe=997$, $p<.0001$), and of Priming Condition ($F(3,33)=25.72$, $MSe=615$, $p<.0001$). The analysis also showed a significant interaction between Type of Ambiguity and Priming Condition ($F(3,33)=5.24$, $MSe=679$, $p<.005$). Again, the discordant condition was mainly responsible for this interaction. Separate analyses for the two ambiguity types showed that the simple main effect of Priming Condition was significant for noun-noun ambiguities ($F(3,33)=10.11$, $MSe=737$, $p=.0001$), as well as for noun-verb ambiguities ($F(3,33)=21.40$, $MSe=557$, $p<.0001$).

Newman-Keuls tests revealed that the discordant priming condition behaved differently for the two types of ambiguity. For the noun-noun ambiguities, significant facilitation was obtained in the concordant condition relative to both the discordant condition and the unrelated baseline. In addition, both the neutral and the discordant condition were faster than the unrelated baseline. The discordant condition thus again showed facilitation relative to the baseline condition. The discordant condition for the noun-verb ambiguities, however, was significantly slower than all other conditions, including the unrelated baseline. Moreover, for the noun-verb ambiguities both the concordant and the neutral condition resulted in reliably faster reaction times than the unrelated baseline.

In summary, as in Experiment 1 the normal control subjects showed the largest amount of facilitation in the concordant priming condition. Again, the discordant condition yielded a different pattern of results for the two

TABLE 6

Means (both across and by Type of Ambiguity) of the median auditory lexical decision times as a function of Priming Condition (ISI=100 msec).

ISI=100 msec	Overall		Noun-Noun		Noun-Verb	
Priming Condition	RT	d	RT	d	RT	d
	Normal Controls (N=12)					
Concordant	665	49	637	59	693	40
Discordant	718	–4	671	25	764	–31
Neutral	682	32	657	39	706	27
Unrelated	714		696		733	
	Broca's Aphasics (N=7)					
Concordant	829	68	764	131	894	4
Discordant	879	18	849	46	909	–11
Neutral	834	63	785	110	884	14
Unrelated	897		895		898	
	Wernicke's Aphasics (N=4)					
Concordant	843	72	827	96	859	48
Discordant	909	6	868	55	949	–42
Neutral	871	44	877	46	865	42
Unrelated	915		923		907	

Differences (d) are measured relative to the unrelated baseline.

types of ambiguity. Relative to the baseline, this condition resulted in facilitation for the noun-noun items, but in inhibition for the noun-verb items.

Patient data showed the same profile as the data of the normal controls, in that relative to the baseline the discordant condition had shorter latencies for the noun-noun ambiguities and longer latencies for the noun-verb ambiguities. The ANOVA on the latency data of the aphasic patients with

Group of Patients as an additional factor did not obtain a significant main effect for Group of Patients ($F<1$). Both the Group of Patients by Priming Condition interaction ($F<1$), and the Group of Patients by Type of Ambiguity by Priming Condition interaction ($F(3,27)=1.65$, $MSe=3109$, $p=.20$) failed to approach significance. A first ANOVA was therefore performed on the pooled group data. It yielded a marginally significant effect of Type of Ambiguity ($F(1,10)=4.05$, $MSe=16016$, $p=.07$), and more importantly, a significant effect of Priming Condition ($F(3,30)=10.86$, $MSe=2221$, $p=.0001$). The latter effect was qualified by a marginally significant interaction between Type of Ambiguity and Priming Condition ($F(3,30)=2.84$, $MSe=3311$, $p=.054$).

Separate analyses of variance for the two types of ambiguity resulted in a significant effect of Priming Condition for the noun-noun ambiguities ($F(3,30)=13.99$, $MSe=2036$, $p<.0001$), but not for the noun-verb ($F(3,30)=1.44$, $MSe=3496$, $p=.25$).

A Newman-Keuls test on the overall differences between the priming conditions showed that the concordant and the neutral condition resulted in significantly faster reaction times than both the discordant condition and the unrelated baseline. The difference between the latter two conditions was not significant.

Inspection of the patient data suggested that the overall priming effect in the Broca's aphasics was mainly due to the noun-noun ambiguities. An ANOVA on their latency data yielded a significant effect of Priming Condition ($F(3,18)=5.86$, $MSe=2647$, $p<.01$). However, this effect was qualified by a marginally significant Type of Ambiguity by Priming Condition interaction ($F(3,18)=2.93$, $MSe=3563$, $p=.06$). Separate analyses for the two ambiguity types revealed that the effect of Priming Condition was significant for the noun-noun ambiguities ($F(3,18)=11.94$, $MSe=2110$, $p<.0005$), but not for the noun-verb ambiguities ($F<1$). Therefore, only the data of the noun-noun items were entered into a post-hoc test. This test revealed that the concordant and the neutral condition resulted in significantly shorter latencies than both the discordant condition and the unrelated baseline. The difference between the discordant and the unrelated condition was significant in a Duncan test ($p<.05$), but just failed to reach significance in a Newman-Keuls test.

An ANOVA on the latency data of the Wernicke's aphasics also yielded a significant main effect of Priming Condition ($F(3,9)=4.78$, $MSe=1919$, $p<.05$). Although the data suggested a different result in the discordant condition for the two ambiguity types, the Type of Ambiguity by Priming Condition interaction failed to reach significance ($F(3,9)=1.86$, $MSe=2202$, $p=.21$). A post-hoc comparison of the overall means of the priming conditions yielded significant facilitation for the concordant condition relative to both the unrelated baseline and the discordant condition. No other significant differences were obtained.

In summary, both patient groups again showed a significant overall priming effect, which in the Broca's aphasics was mainly due to the noun-noun ambiguities. Just as in the normal subjects, the largest amount of facilitation for the noun-noun items emerged in the concordant condition, but the discordant condition also showed a significant amount of facilitation relative to the unrelated baseline. The Broca's aphasics, however, did not show a significant priming effect for the noun-verb items. In contrast to Experiment 1, the results of the Wernicke's aphasics suggested multiple activation of noun-noun ambiguities and selective activation of noun-verb ambiguities, although the interaction of ambiguity type and priming context was not significant.

Error analyses

A summary of the error data for the control subjects, the Broca's aphasics, and the Wernicke's aphasics is given in Table 7. The normal control subjects made errors on only 1% of the critical word target trials. Analysis of the errors on the word targets failed to obtain any significant main effect or interaction. The error data thus do not further qualify the latency data.

The group of Broca's aphasics had an overall error score of 3.2% on the word targets. For the group of Wernicke patients the error score was 6.8%. In an ANOVA with Group of Patients as additional factor, this difference was shown to be not significant ($F(1,9)=1.03$, $MSe=0.0257$, $p=.34$). Moreover, none of the interactions with Group of Patients was significant. An analysis on the pooled group data revealed a marginally significant effect of Priming Condition ($F(3,30)=2.36$, $MSe=0.0042$, $p=.09$), which was qualified by a significant Type of Ambiguity by Priming Condition interaction ($F(3,30)=3.54$, $MSe=0.0012$, $p<.05$). In separate analyses the effect of Priming Condition was found to be not significant for the noun-noun ambiguities ($F(3,30)=1.31$, $MSe=0.0030$, $p=.30$), whereas for the noun-verb ambiguities it was ($F(3,30)=4.27$, $MSe=0.0023$, $p<.05$). This effect was mainly due to the relatively high error percentage for the neutral priming condition. A post-hoc Newman-Keuls test on the means of the noun-verb items in the four priming conditions showed that the neutral condition differed from all the other conditions. Analyses for both patient groups separately did not further qualify the results of the pooled group analysis. The reason for this higher error score of the neutral priming condition compared to the other priming conditions is unclear. It implies, however, that the relatively fast reaction times to noun-verb targets in the neutral condition should be interpreted with some caution, because of a possible speed-accuracy trade-off.

TABLE 7

Mean percentage of errors (both across and by Type of Ambiguity) as a function of Priming Condition (ISI=100 msec).

ISI=100 msec	Overall	Noun-Noun	Noun-Verb
Priming Condition			
	Normal Controls (N=12)		
Concordant	0.5	0.0	1.0
Discordant	1.3	0.5	2.1
Neutral	1.6	1.6	1.6
Unrelated	0.8	1.0	0.5
	Broca's Aphasics (N=7)		
Concordant	2.7	0.9	4.5
Discordant	2.7	0.0	5.4
Neutral	5.8	1.8	9.8
Unrelated	1.8	0.0	3.6
	Wernicke's Aphasics (N=4)		
Concordant	4.7	7.8	1.6
Discordant	2.3	1.6	3.1
Neutral	10.2	9.4	10.9
Unrelated	10.2	12.5	7.8

Introspective report

The interview at the end of the test session revealed that all normal control subjects, all Broca's aphasics, and three of the Wernicke patients had noticed the repetition of the target words. All control subjects said to have been aware of the semantic relations between the words in many of the triplets. Six Broca patients and two Wernicke patients also noticed these semantic relations. Only two control subjects and none of the patients noticed the presence of ambiguous words.

Discussion

The normal control subjects showed essentially the same pattern of results as in Experiment 1. That is, for the noun-noun ambiguities multiple activation of both meanings was again obtained, while the noun-verb ambiguities showed activation for the contextually appropriate reading only. The inhibition obtained for the discordant noun-verb triplets relative to the unrelated baseline might have been caused by a post-lexical semantic matching process, in which attention is allocated to the biased meaning, with the inhibition of the unbiased meaning as its concomitant result (cf. Simpson, 1984). De Groot (1984) has shown that semantic matching can be effective at short prime-target intervals.

The overall priming pattern for both patient groups does not differ substantially from that of the normal controls. Again no interaction between the groups of Broca's and Wernicke's aphasics has been obtained. Both patient groups showed a clear overall priming effect.[9]

This result is strong evidence against the claim by Milberg et al. (1987) that Broca's aphasics have a specific impairment in the automatic processing of lexical-semantic information. If automatic access to lexical-semantic representations had been selectively impaired in Broca's aphasia, the reduction of the ISI to 100 msec should have led to a decrease in the priming effects, since it is generally assumed that at shorter ISIs the effects of ASA are stronger. Despite the increased contribution of ASA to the obtained priming effects at the ISI of 100 msec compared to Experiment 1 with an ISI of 500 msec, no evidence for a reduction in the effects of priming was obtained. The significant priming effects at the shorter ISI, which more heavily relies on ASA, indicates that the deficits in lexical-semantic processing of both Broca's and Wernicke's aphasics cannot be attributed to a substantial impairment in the automatic access of lexical-semantic information.

With respect to Broca's aphasics, Experiment 2 did not resolve the discrepancy between the presence of an overall priming effect in this study and the absence of such an effect in the study by Milberg and his colleagues. Another possible explanation for the discrepancy between both studies is that for some reason the priming effects in Broca patients are shorter lived than in the unimpaired language processing system. In that case priming effects should decrease or disappear completely with longer ISIs. Whereas the priming effects of the supposedly more severe Broca patients in the Milberg et al. study already had disappeared with an ISI of 500 msec, the less severe patients in this study might lose their priming effects with a substantially longer ISI. To test this possibility, in Experiment 3 the ISI was increased to 1250 msec.

In addition to the overall priming effects for both patient groups, two other aspects of the results for the Broca's aphasics should be mentioned. First, the Broca's aphasics showed a clear difference in the size of the priming effects for noun-noun and noun-verb ambiguities. Just like normal controls, the Broca patients showed multiple activation for the noun-noun ambiguities, although the amount of facilitation obtained for discordant triplets is rather weak compared to the amount of facilitation for the concordant and the neutral triplets. Compared to the strong priming effect for the noun-noun ambiguities, the absence of a priming effect for the noun-verb ambiguities is remarkable. Whereas the normal controls and the Wernicke's aphasics showed a large latency difference between the concordant and the discordant noun-verb triplets, this difference for the Broca's aphasics was only 15 msec. This suggests that the Broca's aphasics benefit less or not at all from the form class difference between both readings of the ambiguity. In the general discussion I will come back to possible explanations for this dissociation in the priming effects for noun-noun and noun-verb ambiguities.

The Broca's aphasics differed from the Wernicke's aphasics and the control subjects in another respect. Whereas both normal controls and Wernicke's aphasics had shorter latencies in this experiment compared to Experiment 1, the Broca's aphasics were substantially slower. The seven Broca's aphasics participating in both experiments were on average 95 msec slower with the ISI of 100 msec than with the ISI of 500 msec (860 msec and 765 msec respectively). This difference was significant on a t-test ($t=2.84$, $p<.05$). Whereas the higher rate of presentation induced an increase in the speed of responding in the control subjects and in the Wernicke's aphasics, it caused a decrease in the response times of the Broca's aphasics. One might speculate that an increase in the computational load associated with the perceptual identification (cf. Humphreys, 1985), together with the integration of the three words within the shorter time frame imposed by Experiment 2, is responsible for this delayed responding. Recent findings from another on-line study with Broca's aphasics also suggest a dramatic slowing down of lexical decisions as a consequence of an increase in the processing load (Friederici & Kilborn, 1989; the authors, however, give a different explanation for their results).

Experiment 3

In Experiment 3 the ISI between the members of the triplets was increased to 1250 msec. Apparatus and procedure were exactly the same as in Experiment 2.

Method

Subjects
The same group of eleven aphasic patients as in Experiment 2, and another group of twelve right-handed normal control subjects participated in Experiment 3. The normal controls were approximately matched in age and education with the aphasic patients. The mean age of the control subjects was 62.6 years (range: 48-71). None of the control subjects had participated in one of the preceding experiments. The time interval for the aphasic patients between the test sessions of Experiment 2 and Experiment 3 was at least four weeks. Apparatus and procedure were the same as in Experiment 2.

Materials
Three new tapes were constructed, two test tapes and one practice tape. They only differed from the tapes of the previous experiments in the interval of silence between the members of the triplets. With the help of a speech waveform editing system the interval was increased to 1250 msec. The interval of silence between the triplets was again 4 seconds.

Results

Results were analysed as in the Experiments 1 and 2. A summary of the results is given in Table 8.

Latency analyses
For the group of normal controls the ANOVA yielded significant main effects for both Priming Condition ($F(3,33)=22.89$, $MSe=769$, $p<.0001$) and Type of Ambiguity ($F(1,11)=5.75$, $MSe=6887$, $p<.05$). The overall priming effect was again qualified by a significant interaction between Type of Ambiguity and Priming Condition ($F(3,33)=4.92$, $MSe=947$, $p<.01$). Separate ANOVAs were therefore performed for the two ambiguity types. These revealed a significant effect of Priming Condition for both types of ambiguity (for the noun-noun ambiguities: $F(3,33)=7.40$, $MSe=1088$, $p<.001$; for the noun-verb ambiguities: $F(3,33)=22.63$, $MSe=628$, $p<.0001$). Inspection of Table 8 suggests a different effect of the discordant priming condition on the two ambiguity types, just as in Experiments 1 and 2. The discordant condition again showed facilitation relative to the unrelated baseline for the noun-noun ambiguities, and inhibition for the noun-verb ambiguities.

For the noun-noun ambiguities, a Newman-Keuls test showed significantly faster reaction times in the concordant condition relative to all other priming conditions. The facilitation of the neutral and the discordant condition relative to the unrelated baseline, however, just failed to reach significance. For the noun-verb ambiguities, the discordant condition resulted in significantly slower reaction times than all other conditions. Both concordant and neutral priming conditions were significantly faster than the unrelated baseline.

TABLE 8

Means (both across and by Type of Ambiguity) of the median auditory lexical decision times as a function of Priming Condition (ISI=1250 msec).

ISI=1250 msec	Overall		Noun-Noun		Noun-Verb	
Primin-g Condition	RT	d	RT	d	RT	d
	Normal Controls (N=12)					
Concordant	705	52	685	62	725	41
Discordant	766	-9	726	21	806	-40
Neutral	734	23	723	24	745	21
Unrelated	757		747		766	
	Broca's Aphasics (N=7)					
Concordant	818	32	786	74	849	-9
Discordant	819	31	782	78	856	-16
Neutral	831	19	816	44	846	-6
Unrelated	850		860		840	
	Wernicke's Aphasics (N=4)					
Concordant	853	57	837	39	870	75
Discordant	879	31	852	24	906	39
Neutral	867	43	874	2	859	86
Unrelated	910		876		945	

Differences (d) are measured relative to the unrelated baseline.

In conclusion, for the normal control subjects the shortest latencies were again obtained in the concordant condition. In the discordant condition, noun-verb items showed inhibition relative to the baseline, while noun-noun items showed a non-significant facilitatory trend.

The ANOVA on the latency data of the patients with Group of Patients as additional factor, did not yield a significant main effect of Group of Patients ($F<1$), and more importantly, neither a significant interaction between Group of Patients and Priming Condition ($F<1$), or a significant Group of Patients by Type of Ambiguity by Priming Condition interaction ($F(3,27)=2.21$, $MSe=2155$, $p=.11$). The ANOVA on the pooled group data yielded a significant main effect for Type of Ambiguity ($F(1,10)=6.09$, $MSe=4641$, $p<.05$). The effect of Priming Condition, however, only approached significance ($F(3,30)=2.46$, $MSe=2795$, $p=.082$), indicating that the priming effect is less stable compared to the effects obtained with shorter ISIs. The interaction between Type of Ambiguity and Priming Condition failed to reach significance ($F(3,30)=1.71$, $MSe=2416$, $p=.19$).

Inspection of the patient data revealed that for the Broca's aphasics the size of the priming effects again seemed much larger for the noun-noun ambiguities than for the noun-verb ambiguities. An ANOVA on the latency data of these subjects did not yield a significant effect of Priming Condition ($F<1$). However, the interaction between Type of Ambiguity and Priming Condition reached significance ($F(3,18)=3.34$, $MSe=1858$, $p<.05$). Separate analyses for the two types of ambiguity showed a marginally significant effect of Priming Condition for the noun-noun ambiguities ($F(3,18)=2.77$, $MSe=3283$, $p=.072$), but no significant priming effect for the noun-verb ambiguities ($F<1$). A Newman-Keuls test did not result in significant differences between the means of the noun-noun items in the four priming conditions.

An ANOVA on the latency data of the Wernicke's aphasics showed that neither the effect of Priming Condition ($F(3,9)=2.63$, $MSe=1799$, $p=.11$) nor the interaction between Type of Ambiguity and Priming Condition ($F<1$) approached significance.

In summary, neither of the two patient groups showed a significant overall priming effect, and once again an interaction between patient group and priming context could not be established.

Error analyses

A summary of the error scores for the three subject groups is given in Table 9. Normal control subjects had an overall error percentage on the word targets of less than 1%. As in Experiments 1 and 2, the analysis of the error data showed that all main effects and interactions failed to reach significance, again indicating the absence of a speed-accuracy trade-off.

TABLE 9

Mean percentage of errors (both across and by Type of Ambiguity) as a function of Priming Condition (ISI=1250 msec).

ISI=1250 msec	Overall	Noun-Noun	Noun-Verb
Priming Condition			
	Normal Controls (N=12)		
Concordant	0.8	1.0	0.5
Discordant	0.5	0.5	0.5
Neutral	0.8	1.0	0.5
Unrelated	1.3	1.6	1.0
	Broca's Aphasics (N=7)		
Concordant	3.1	3.6	2.7
Discordant	2.7	1.8	3.6
Neutral	3.6	2.7	4.5
Unrelated	3.1	1.8	4.5
	Wernicke's Aphasics (N=4)		
Concordant	6.3	9.4	3.1
Discordant	4.7	4.7	4.7
Neutral	4.7	3.1	6.3
Unrelated	5.5	6.3	4.7

The Broca's aphasics had an overall error percentage of 3.1% on the word targets. For the Wernicke's aphasics, the overall error score was 5.3%. An ANOVA with Group of Patients as additional factor revealed that this difference was not significant ($F(1,9)=1.13$, $MSe=0.0083$, $p=.31$). Moreover, none of the interactions with Group of Patients was significant. Further analyses were, therefore, done on the pooled group data. The analysis on the pooled group data did not obtain significant main effects for Type of Ambiguity and Priming Condition (both $Fs<1$). The interaction between Type of Ambiguity and Priming Condition also failed to reach significance ($F(3,30)=2.02$, $MSe=0.0014$, $p=.13$). Separate analyses for both patient groups did not deviate from the results of the pooled group analysis.

Introspective report
As in the other two experiments, almost all control subjects and Broca's aphasics had noticed the semantic relation between the words in a subset of the triplets, and the repetition of the targets. Two Wernicke's had been aware of these repetitions, and only one confirmed to have noticed the semantic relations between primes and targets. Again, no single patient showed any awareness of the ambiguous nature of a subset of the primes. Only three control subjects noticed the presence of words with two independent meanings.

Discussion

The group of normal controls showed the same pattern of results as found in Experiment 2. Although the latency difference between the discordant and the unrelated noun-noun triplets just failed to reach significance, the trend of multiple activation for the noun-noun ambiguities is consistent with the results of the two previous experiments. For the noun-verb ambiguities significant inhibition was again obtained in the discordant condition, indicating the contribution of controlled processing to the priming effects. As in the previous experiments the largest amount of facilitation emerged in the concordant condition for both noun-noun and noun-verb items.

The results for the aphasic patients differed from the two previous experiments in that with an ISI of 1250 msec a significant priming effect was no longer obtained. Although the overall trend of the results is in the same direction as in Experiment 2, the priming pattern is no longer stable at this relatively long ISI. This, again, holds equally for both types of patients. It indicates that in Broca's and Wernicke's aphasics priming effects are shorter lived than in normal control subjects. Increasing the ISI between the words of the target triplets has resulted in a shift from highly significant overall priming effects at 100 msec, to non-significant priming effects at 1250 msec. This suggests that in these aphasic patients either the automatic spread of activation shows a faster decay, or the controlled processing of lexical-semantic information is impaired. I will come back to these different explanations in the general discussion.

Finally, the absence of an interaction between priming context and group of aphasic patients in the three priming experiments is in clear contrast with the results of studies in which aphasic patients are required to make explicit semantic judgements (Goodglass & Baker, 1976; Whitehouse et al., 1978; Zurif et al., 1974). In these studies, Wernicke patients are consistently reported to perform worse than Broca's aphasics. To test whether this pattern of results could be replicated with the same Wernicke's and Broca's aphasics who participated in the previous three experiments, Experiment 4 tested these patients with an explicit semantic judgement task.

Experiment 4

This experiment is done to test whether a completely different task with a subset of the materials used in Experiments 1 to 3, results in a different pattern of performance for the two patient groups. In Experiment 4 subjects are explicitly asked to give their judgements as to whether the words in auditorily presented word pairs go together semantically or not. The experimental word pairs consist of the first two words of the concordant, discordant and neutral triplets forming the primes in the lexical decision experiments. The priming effects in Experiments 1 and 2 were attributed to the effects of the prime contexts, which consisted of the first two words of the triplets. As indicated by the results of the previous experiments, the semantic information specified in the lexical entries of these words could be accessed in an implicit way. However, this does not necessarily mean that the same items can be elaborated on in an explicit memory task. This experiment is done to test how accurate patients are under task aspects which require them to explicitly judge the semantic aspects of the materials.

Method

Subjects

Eight elderly subjects from the MPI subject pool served as the normal controls. The control subjects were approximately matched in age and education with the aphasic patients. The same group of seven Broca's aphasics and four Wernicke's aphasics that participated in Experiments 1, 2, and 3 was tested.

Materials

The materials for this experiment were selected from the materials used in the previous experiments. Twenty of the 32 ambiguous words were used. They consisted of all the noun-noun ambiguities, and four noun-verb ambiguities (three of which were in the citation form for both the noun and the verb reading; e.g., *kussen*). The critical word pairs were created from the first two words of the triplets in the previous experiments. For each ambiguous word two related word pairs were constructed, one for each reading (e.g., *kater-bier*; "tomcat/hangover-beer"; *poes-kater*; "cat-tomcat/hangover"). In addition, three unrelated word pairs were created. One contained the two primes from the neutral priming condition (e.g., *piano-kater*; "piano-tomcat/hangover"). The other two were constructed by combining the unambiguous first primes (e.g., *bier-piano*; "beer-piano"; *bier-poes*; "beer-cat"). These latter pairs served as fillers to prevent the development of strategies based on the repetition of ambiguous words. This resulted in a total number of 100 word pairs, 40 related and 60 unrelated. In addition 8 word pairs were constructed to be used as practice items.

A test tape was constructed using the same tokens as in the previous experiments. The test tape presented the word pairs in a randomized sequence, with the constraint that word pairs sharing one word were separated by at least four other word pairs. The interval of silence between the two members of a word pair was 500 msec.

Apparatus
The apparatus for Experiment 4 consisted of a Uher 4400 tape recorder, and two pairs of Sennheiser HD 224 closed headphones (one for the subject and another for the experimenter).

Procedure
Subjects were tested individually during one session. They were told that they would hear a series of word pairs, some of which consisted of two words that were in some way related in meaning, and others consisting of two words that were unrelated in meaning. Subjects were required to indicate for every word pair whether the two words went together semantically, by pointing to a card saying YES, or whether the two words were unrelated in meaning by pointing to a card saying NO. After every word pair, the experimenter stopped the tape, wrote down the subject's response and started the tape recorder again to present the next pair to the subject. No feedback was given to the subjects during the presentation of the experimental word pairs.

Results

Only the responses to the word pairs derived from the concordant, discordant, and neutral triplets of the previous lexical decision experiments were scored (40 related and 20 unrelated pairs). To separate the subject's sensitivity to the semantic relations from his/her response bias, the non-parametric index of sensitivity, A^1, was computed for each subject. This measure is derived from signal-detection analysis (Green & Swets, 1966; Grier, 1971). The A^1 value (e.g., 0.90) can be interpreted as the expected score of that percentage correct (e.g., 90%) on a forced two-choice procedure (Linebarger, Schwartz, & Saffran, 1983a). The A^1s for the individual subjects are given in Table 10.

TABLE 10

A^1–scores for the individual subjects in the semantic judgement task.

Subjects	1	2	3	4	5	6	7	8
Normal Controls	0.82	0.93	0.87	0.87	0.87	0.95	0.93	0.91
Broca's Aphasics	0.92	0.90	0.79	0.70	0.90	0.72	0.78	
Wernicke's Aphasics	0.81	0.69	0.65	0.74				

The subject numbers of the aphasic patients correspond to the order in which they are listed in Table 1.

Because the means and variances are correlated for A^1-scores, they were first submitted to an arcsin-transformation (Winer, 1971). The transformed data were entered into an ANOVA with Group of Subjects (Normal Controls, Broca's Aphasics, Wernicke's Aphasics) as the only factor. The analysis yielded a significant effect for Group of Subjects ($F(2,16)=8.26$, $MSe=52.7$, $p<.005$). The group of normal controls showed the highest mean A^1-score (0.89). The mean score of the group of Broca's aphasics (0.82) was higher than the one of the Wernicke's aphasics (0.72). A post-hoc Newman-Keuls test showed that the group of Wernicke patients had a significant lower score than both the Broca's aphasics and the normal controls. The scores of the Broca's aphasics and the normal controls, however, did not differ significantly.

Discussion

Although their performance was above chance, the Wernicke's aphasics showed a clear deficit in explicitly judging the semantic relations between words. This result is in agreement with the findings obtained in previous studies which required the patients to make semantic judgements of some sort (e.g., Goodglass & Baker, 1976; Whitehouse et al., 1978; Zurif et al., 1974). However, the same word pairs that were used for the semantic judgements, induced the priming effects obtained for these patients in Experiments 1 and 2. Moreover, whereas the Wernicke's aphasics and the Broca's aphasics did not differ in their overall pattern of results in the priming experiments, the two groups of patients showed a difference in the semantic judgement task. This dissociation of results indicates that the semantic deficits in Wernicke's aphasia are not so much due to a deficit in automatically accessing the mental lexicon, but to an impairment in operating on the lexical-semantic information in explicit memory tasks.

The qualitative differences in results obtained with different tasks in normal subjects (e.g., Graf & Mandler, 1984), and the patterns of dissociation seen in a range of neuropsychological disorders, such as prosopagnosia, alexia, Korsakoff's syndrome, or blindsight (e.g., Renault, Signoret, Debruille, Breton, & Bolgert, 1989; Shallice & Saffran, 1986; Verfaellie, Cermak, Blackford, & Weiss, 1989; Volpe, LeDoux, & Gazzaniga, 1979; Weiskrantz, 1986) have documented the differences between implicit and explicit memory (see Schacter, 1987). Although it is still an unsettled issue whether implicit and explicit memory refer to different retrieval mechanisms (e.g., automatic vs. controlled processing) or to different underlying systems (e.g., procedural vs. declarative memory; Squire & Cohen, 1984), a growing body of data suggests that the distinction is useful (Schacter, 1987). Explicit memory is revealed when subjects are required to consciously elaborate on materials accessed in memory (Graf & Mandler, 1984). In contrast to access, elaborative processing is claimed to require considerable attentional resources (Graf & Mandler, 1984).

It is in experiments tapping this explicit memory that Wernicke's aphasics show their semantic deficits. This suggests that the comprehension impairments of these patients are not caused by a deficit in accessing the mental lexicon, but might arise in the post-lexical process of integrating/elaborating the lexical-semantic information into a higher-order message representation (see also Milberg & Blumstein, 1981).

To allow the elaboration of materials accessed in semantic memory (e.g., necessary for the construction of a message representation of the utterance in the context of the current discourse), it is likely that the semantic information has to be integrated into an episodic memory representation of the message and its context. Although the distinction between semantic and episodic memory is not very clear-cut, and although the evidence for this distinction is still a matter of debate (see Tulving, 1984, 1987), it nevertheless seems to cover the broad distinction between the mental lexicon (a subset of semantic memory) as "a repository of declarative knowledge about the words of [the speaker/hearer's] language"

(Levelt, 1989; p. 182), and the situationally marked discourse model as part of the person's episodic memory.

The lexical decision experiments reported above allow us to test whether the impairment of the Wernicke patients in semantic tasks requiring explicit semantic judgements is due to a deficit in forming episodic traces. This can be done by looking at the repetition effects for the target words. During the test session the target words were repeated four times. It has been claimed that delayed repetition effects demonstrate that subjects have formed an episodic memory trace on the basis of the previous presentation of the words (Evett & Humphreys, 1981; Feustel, Shiffrin, & Salasoo, 1983; Humphreys, 1985). The effects of repetition priming have been shown to be independent of the lexical activation processes involved in semantic priming (Den Heyer, Goring, & Dannenbring, 1985). At the same time, repetition priming is one of the most widely used measures in tapping implicit memory (Tulving & Schacter, 1990).[10] The repetition effects in the present priming study thus allow us to answer the question whether the Wernicke's aphasics have a deficit in forming episodic memory traces or an independent and specific impairment in consciously operating on automatically accessed lexical-semantic information.

To test the effects of repetition priming for the control subjects and for the eleven aphasic patients who participated in the three lexical decision experiments, the data of Experiments 1 to 3 were taken together. Table 11 summarizes the results for the control subjects and the two aphasic patient groups.

TABLE 11

Means (collapsed over the ISIs in Experiments 1, 2, and 3) of the median auditory lexical decision times as a function of Index of Presentation.

Index of Presentation	RT	d	RT	d	RT	d
	Normal Controls (N=36)		Broca's Aphasics (N=7)		Wernicke's Aphasics (N=4)	
First Presentation	777		857		967	
Second Presentation	713	64	792	65	900	67
Third Presentation	714	63	808	49	885	82
Fourth Presentation	709	68	804	53	880	87

Differences (d) are measured relative to the first presentation.

In the analysis, all target words with the same index of presentation (first, second, and so on) were grouped together. Analyses of variance with Index of Presentation (four levels) and ISI (three levels) as factors were done for the three subject groups separately. A significant main effect for Index of Presentation was obtained for the control subjects ($F(3,99)=48.62$, $MSe=1563$, $p<.0001$), the Broca's aphasics ($F(3,18)=11.52$, $MSe=2979$, $p<.001$), and also for the Wernicke's aphasics ($F(3,9)=15.02$, $MSe=2464$, $p<.001$). No significant interactions between Index of Presentation and ISI were obtained. Post-hoc Newman-Keuls tests showed that for all three subject groups significantly longer latencies were obtained on the first presentation than on all the following presentations. The differences between second, third and fourth presentation were not significant. So, it can be concluded that the Wernicke's aphasics showed the same repetition effects as the Broca's aphasics and the normal control subjects.

This result suggests that the impairment which Wernicke patients show in consciously operating on lexical-semantic information cannot be attributed to a deficit in forming episodic memory traces.

General discussion

The aim of this study was to test recent claims about impairments in either automatic or controlled access of lexical-semantic information in Broca's and Wernicke's aphasia (Blumstein et al., 1982; Milberg & Blumstein, 1981; Milberg et al., 1987). The resolution of lexical ambiguity in a word priming context served as the vehicle to study possible deficits in accessing lexical meanings in a group of aphasic patients.

With respect to the processing of ambiguous words in a priming context, it has been claimed that initially all meanings of an ambiguous word are accessed automatically (Holley-Wilcox & Blank, 1980; Simpson, 1984; Marcel, 1980). After the initial access of the different meanings, the context is used to select the appropriate reading. According to Tanenhaus et al. (1979), the resolution of lexical ambiguity can be characterized as a veiled controlled process. Shiffrin and Schneider (1977) divided controlled processes into two classes: veiled and accessible. In contrast to the accessible controlled processes, the veiled controlled processes are opaque to introspection and insensitive to manipulation through instruction. This enables them to be faster than the accessible ones. The inability of the vast majority of the subjects to report the presence of ambiguous words testifies to their unawareness of this aspect of the materials used in the experiments. It suggests that the suppression of the inappropriate reading of ambiguous words does not require awareness of their multiple meaning character, supporting the claim that ambiguity resolution is indeed a veiled process. The inhibition shown by the normal control subjects in Experiment 2 and 3 for the discordant noun-verb triplets supports the claim that the suppression of the inappropriate reading is a post-lexical process. This process most likely reflects the integration of the first word prime with the biased meaning of the ambiguous word, resulting in inhibition for targets related to the unbiased meaning. Post-lexical integration processes (i.e., semantic matching) already manifest themselves at short intervals between primes and targets (De Groot, 1984).

The normal control subjects showed the same pattern of results for all three ISIs. It is therefore difficult to separate at the level of the reported data priming effects due to automatic activation spreading from expectancy-induced priming effects. Thus it must be done in an indirect way. It has been argued (Neely, 1977, 1990; Posner & Snyder, 1975) that the contribution of automatic spread of activation to priming effects increases with decreasing ISIs (or SOAs). Although the time range of ASA is only fairly well established for the visual domain, an ISI of 100 msec between auditorily presented words is short enough on any account of priming to pick up on the effects of automatic spread of activation. It is therefore very likely that ASA had its strongest contribution to the obtained priming effects in Experiments 2, most likely also contributed to the priming effects in Experiment 1, but had its weakest contribution in Experiment 3, if at all.

Figures 1 and 2 present the overall priming effects at the three ISIs for the normal control subjects and for the aphasic patients who participated in all experiments. As can be seen, the aphasic patients showed the normal priming pattern at the short ISIs. At the ISI of 1250 msec, the aphasic patients deviated from the normal control subjects in that significant priming effects were no longer obtained. This holds for both Broca's and Wernicke's aphasics equally. A summary of the individual subject data is given in Appendix 2.

These results are strong evidence against the claim by Milberg et al. (1987) that Broca's aphasics are impaired in automatically accessing lexical-semantic information. Even at an ISI as short as 100 msec the overall pattern of results for the Broca's aphasics did not differ from that of the normal control subjects. To date no other semantic priming study has used an interval short enough to allow firm conclusions with respect to the effects of automatic lexical-semantic processing in aphasic patients. The SOA of 2000 msec in the study by Milberg and Blumstein (1981) using a visual presentation, or the ISI of 500 msec in studies using an auditory presentation (Blumstein et al., 1982; Chenery et al., 1990; Katz, 1988; Milberg et al., 1987, 1988) are not short enough to guarantee that these studies mainly tapped the automatic spread of activation between related nodes in the semantic lexicon. Moreover, given the long latencies reported for the patients in these studies (between an estimated average of 1400 msec for the Broca's aphasics and 2100 msec for the Wernicke's aphasics), post-lexical strategic effects cannot be excluded. Conclusions with respect to possible impairments in automatic lexical-semantic processing in certain aphasic syndromes require the use of a range of SOAs (ISIs), including short ones that can be assumed to strongly tap the automatic spread of activation on the basis of well-established results in the priming literature (e.g., Neely, 1977, 1990). In addition, the experimental procedure should ensure that the measurement is as on-line as possible. That is, one has to be sure that the aphasic patients respond as quickly as possible given the general effects of their brain damage. The present research using both short and long ISIs indicates that neither Wernicke nor Broca patients have a specific deficit in automatic lexical-semantic processing.

With an increase in the ISI between the words, however, the aphasic patients started to show a pattern diverging from that of the normal control subjects. An ISI of 1250 msec between the primes and the target no longer resulted in a reliable priming effect for both groups of aphasic patients. Priming effects thus are shorter lived in aphasic patients than in normal control subjects. This reduction in the life span of semantic priming can be explained in different ways.

One possible explanation is that (the spread of) activation decays more rapidly in the mental lexicon of the aphasic patients. As a consequence, the contribution of ASA to the overall priming effects covers a shorter time range than in the unimpaired language processor. Whereas in normal subjects residual priming due to ASA is still part of the overall priming effect at longer ISIs, in aphasic patients ASA might no longer contribute to priming effects at relatively long intervals. The faster decay can be caused by a higher decay rate of the activation collected by a semantic node in the lexicon, or by a reduction in the initial levels of activation due to a general reduction in the signal-to-noise ratio for semantic nodes. Because the spread of activation to related nodes in the lexicon is a function of the activation collected by the source node, a reduction in its activation level will lead to a faster return to a resting level of activation. Consequently, a reduced temporal window for the automatic spread of activation will result.

Another explanation for the reduction of the priming effects with increasing ISIs focuses on the controlled processing of semantically related words. If controlled processes have their major contributions to priming effects at longer ISIs, the reduction in priming seen with longer ISIs might be caused by an impairment in controlled processing. The patients might

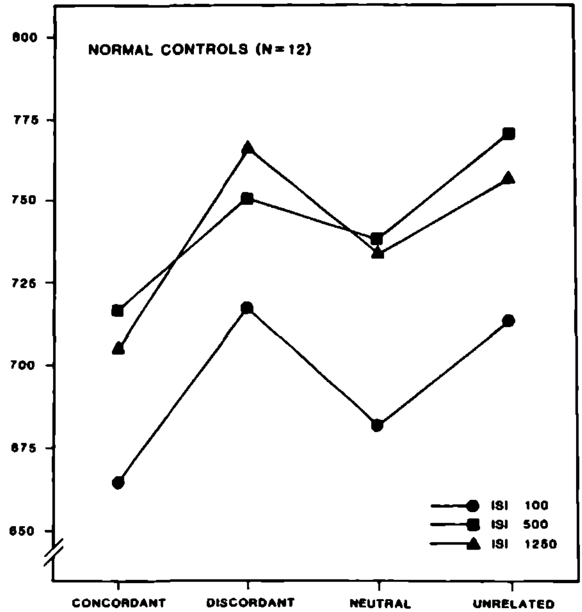

Figure 1: Means of normal control subjects' median lexical decision latencies as a function of Priming Condition.

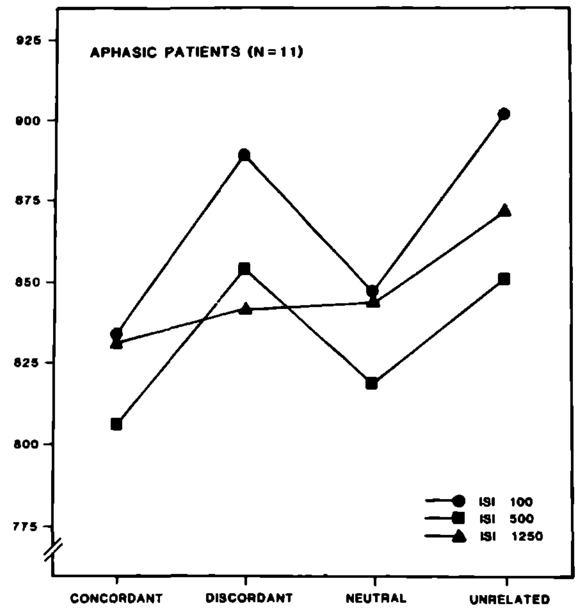

Figure 2: Means of the aphasic patients' median lexical decision latencies as a function of Priming Condition.

have difficulties in generating and retaining a set of expected targets from the primes, or in checking the semantic coherence of the words in the input string. In contrast to the automatic spread of activation, generating an expectancy set or checking the semantic coherence requires some form of computation. If patients are impaired in this type of computation, it would indicate that their comprehension deficits are beyond the level of automatic lexical access. The functional locus of these deficits might be post-lexical, for instance in the integration of accessed lexical information into a higher-order semantic representation of the whole utterance. With respect to the Wernicke's aphasics, this interpretation is corroborated by the relatedness judgement data. With respect to the Broca's aphasics, their increase in overall RTs at the shortest ISI indicates the possibility of a reduction in the computational resources required for these forms of controlled processing. The experiments reported in the next chapter focus, among other things, on the post-lexical aspects of the comprehension deficits in aphasic patients.

To date the priming studies done with aphasic patients are very limited in number, and do not provide us with sufficiently detailed empirical data to decide between the explanations given. More research is therefore needed. However, the results to be presented in the next chapters are most consistent with the second type of explanation, as will be made clear in chapter 6.

For the Broca's aphasics, the overall priming effects were mainly due to the noun-noun ambiguities. Only the ISI of 500 msec resulted in a significant priming effect for the noun-verb ambiguities. The absence of a stable priming effect for the noun-verb ambiguities even with a short ISI, is not easy to explain. The morphological make-up of the noun-verb ambiguities used in this study might be involved in dampening the effects of priming.

In contrast to most English noun-verb ambiguities (e.g., *watch*) used in studies on the resolution of lexical ambiguity (Seidenberg et al., 1982; Tanenhaus et al., 1979), the majority of the Dutch noun-verb ambiguities in this study were morphologically complex, consisting of a stem and an inflectional suffix (e.g., *wijk-en*). In Dutch, the inflectional suffix *-en* is one of the plural markers for nouns. For verbs presented in isolation it indicates the infinitival form. All sixteen noun-verb ambiguities in this study were in the infinitival verb form, while twelve referred to the plural reading of the noun and four to its nominative singular form.

It has been claimed that agrammatic patients have a specific deficit in the processing of free standing and bound closed class morphemes serving a syntactic function (e.g., Bradley, Garrett, & Zurif, 1980; Friederici, 1983, 1988a, 1988b; Tyler, Behrens, Cobb, & Marslen-Wilson, 1990; Tyler &

Cobb, 1987). The proposed impairment in the access of syntactic information associated with inflectional suffixes might have hampered the identification of the grammatical form class of the morphologically complex word forms used in the present priming studies.[11] Although automatic semantic priming does not require the processing of the inflectional ending (cf. Tyler & Marslen-Wilson, 1986; Zwitserlood, 1989), priming effects might have been partially masked by interference effects which possibly arose as a consequence of the impairment in rapidly using the suffixal information to determine the form class of the noun-verb ambiguities. In this respect it is worth mentioning that only one of the sixteen unrelated baseline triplets contained a second prime with a morphologically complex word form. Priming effects in the other three triplet types were weak or absent relative to the morphologically simple, unrelated baseline.

An additional explanation for the absence of a stable pattern of differential activation for concordant and discordant noun-verb triplets could be found in the morphological asymmetry between the verb and the noun readings. Although both are morphologically complex in the majority of cases, there is a clear difference in their markedness. The verb-infinitive in Dutch is morphologically unmarked, while the plural form of the noun is clearly marked (Lapointe, 1985). In language production, agrammatic patients have a tendency to substitute the unmarked verb infinitive for verb forms marked for person and tense (Lapointe, 1985; Goodglass & Geschwind, 1976). They might show an analogous preference in language comprehension to assign a word form its most unmarked interpretation. This would predict that independent of context, the Broca patients show a tendency to interpret the noun-verb ambiguities as referring to their verb-readings.

Whether this explanation holds can easily be tested. Because half of the targets in the set of noun-verb triplets were related to the noun reading and half to the verb reading, a preference for the verb reading is indicated by an interaction between priming condition and the form-class relatedness of the targets. A preference for the verb reading would induce facilitation for the verb-related targets relative to the unrelated baseline (e.g., *stelen-dief* vs. *veiling-dief*; "steal-thief" vs. "auction-thief"), but not for the noun-related targets (e.g., *polsen-horloge* vs. *recept-horloge*; "wrists-watch" vs. "recipe-watch"). An analysis of variance on the latency data of the noun-verb triplets for the three ISIs including the factor Form-Class Relatedness revealed that the interaction between Form-Class Relatedness and Priming Condition did not approach significance for the group of Broca's aphasics ($F<1$). The normal control subjects also failed to show a significant interaction between the two factors. This implies that the absence of differential priming effects for the concordant and discordant noun-verb triplets cannot be attributed to a preference to assign the noun-verb ambiguities their unmarked verb reading instead of their marked noun reading.[12] A markedness effect, however, has been found in a context that biased either the noun or the verb reading via syntactic instead of semantic constraints (see chapter 5).

Although the data do not allow a very detailed specification of the additional underlying impairment of the Broca's aphasics, it can be suggested that the selective decrease in the priming effects for the noun-verb ambiguities has something to do with an impairment in either the on-line morphological parsing of the complex word forms into a stem and an inflection, or the on-line exploitation of the syntactic implications of the inflectional suffix. This might hamper access to the form class information, which otherwise would have contributed to the selection of the contextually appropriate, and the suppression of the inappropriate reading of the ambiguity.

The impairment Wernicke patients show when explicitly asked to judge the semantic relations between words, indicates that this type of task taps a different set of retrieval processes than the priming tasks do. The impairment of these patients in consciously elaborating on lexical-semantic information, however, does not necessarily mean that the representational structure of their semantic memory is disturbed. The priming effects obtained for the Wernicke's aphasics in this and other studies (Blumstein et al., 1982; Milberg & Blumstein, 1981; Milberg et al., 1987) suggests quite clearly that the integrity of their semantic memory is preserved. Moreover, the normal repetition effects obtained for these patients indicate that they are able to form episodic traces, a prerequisite for the construction of a message representation from the speech input. However, their ability to consciously elaborate on linguistic material seems to be reduced. As in different forms of amnesia, one could characterize this specific deficit as "an impairment of consciousness" (Tulving, 1987; p. 75) rather than a disintegration of the underlying stored knowledge base.

4

TRACKING THE TIME COURSE OF MEANING SELECTION IN APHASIA: SENTENTIAL-SEMANTIC CONTEXT EFFECTS

The aim of this study is to further determine the functional locus of comprehension deficits in aphasic patients, especially Broca's and Wernicke's aphasics. Recent research using on-line methods in testing aphasic patients suggests that the comprehension deficits in Broca's and Wernicke's aphasics are in many cases computational in nature (e.g., Baum, 1988, 1989; Blumstein, Milberg, & Shrier, 1982; Friederici, 1985; Friederici & Kilborn, 1989; Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1987; Shankweiler, Crain, Gorrell, & Tuller, 1989; Swinney, Zurif, & Nicol, 1989; Tyler, 1988; Tyler & Cobb, 1987). That is, these deficits are not so much caused by a (partial) loss of stored knowledge representations required for language processing, but more by a (partial) inability to access and exploit these knowledge representations on-line during the process of language comprehension (or in experimental tasks such as sentence-picture matching and object manipulation). To track these computational deficits, it is essential to tap the comprehension process as it unfolds in real time. This requires the use of on-line measures for which the subjects' responses are assumed to be time-locked to the level of processing under study.

One of the most remarkable characteristics of speech processing is its speed. For a smooth operation of the speech processing system it is, therefore, necessary that the required sources of information (e.g., lexical, syntactic, pragmatic) are made available at the appropriate moments in time. Changes in the temporal organization of the comprehension process might be responsible for comprehension deficits in certain forms of aphasia. If lexical meanings become available to the language processor in a slower-than-normal rate, or if their integration into a message level representation is relatively delayed, problems in the temporal coordination of the different processes involved in language comprehension might arise.

To test the time course of language comprehension in aphasic patients with mild and more severe comprehension deficits, this study will focus on the temporal aspects of the process of selecting the contextually appropriate reading of words with multiple meanings. In order to specify in more detail the research questions being addressed, a delineation of the different functional aspects of the language comprehension process will be given first.

The influence of sentential-semantic context on lexical processing

The language comprehension system is designed to construct a message representation from the words uttered by the speaker. Central in this respect is the process of spoken word recognition. In the process of word recognition the sensory input is mapped onto the mental lexicon, containing knowledge representations that link the form aspects of words to their syntactic and semantic specifications. In this way the language processor is provided with activated word senses that have to be integrated on-line into a higher-level message representation. The overall process of word recognition can be functionally divided into three parts: access, selection and integration (Marslen-Wilson, 1987; Zwitserlood, 1989). The access function involves the mapping of a representation extracted from the sensory input onto word-form representations stored in the mental lexicon, resulting in the activation of the syntactic and semantic attributes associated with these form representations. The selection function concerns the selection of the element that best matches the input from the ensemble of accessed lexical entries. Finally, the integration function serves the purpose of integrating the syntactic and semantic information associated with the activated lexical elements into a higher-level message representation.

Two interrelated questions are of central concern for research on spoken word recognition. First, how are these three functions distributed and coordinated in time? Second, what kinds of information influence the operation of these functions? With respect to the latter question especially the role of context has been the subject of much dispute (cf. Frauenfelder & Tyler, 1987). Normally, words are not processed in isolation but in the context of an utterance (e.g., in fluent conversation). Normally, lexical processing, therefore, depends on two broad classes of information: lower-level representations constructed from the sensory input, and higher-level representations constructed from the context preceding the word to be processed. These higher-level message representations contain semantic restrictions on possible word candidates which do not so much arise from the specific lexical meanings of the individual words in the context, as from the overall meaning of the utterance within the scope of the current discourse (cf. Seuren, 1985). Disparate views are held as to the stage of lexical processing at which the bottom-up and top-down analyses interact. According to autonomous theories of lexical processing (e.g., Forster, 1979; Tanenhaus, Carlson, & Seidenberg, 1985) context cannot influence lexical access and selection. Only after the word has been recognized, context comes into play in integrating the output of the lexical processes into the higher-level message representation. In contrast, according to fully interactive models, such as Morton's Logogen model (Morton, 1969, 1979), and connectionist type models (McClelland & Elman, 1986; McClelland & Rumelhart, 1981), in principle context can have its effect on every stage of lexical processing. Even before any sensory input is available to the system, context can change the activation levels of lexical elements, thereby increasing the chance for contextually appropriate elements to be selected. A position in between these two extremes is taken by the Cohort model (e.g., Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978). According to this model, lexical access is fully dependent on the sensory input. This sensory input activates in parallel a set of potential word candidates which then is reduced in size during the selection phase on the basis of further acoustic-phonetic information. Context, however, can speed up this selection process by de-activating those lexical elements that, although consistent with the sensory input, are inappropriate given the context (cf. Zwitserlood, 1989).

An important role both in testing the claims of autonomous and interactive models, and in tracking the time course of lexical processing has been reserved for studies on the resolution of lexical ambiguity in a sentence context (cf. Simpson, 1984). Lexical ambiguity arises in words which share their form representation, but which have different unrelated meanings (e.g., *bank; watch*). Because of their shared form representation, the different meanings of an ambiguous word cannot be differentiated on the basis of the sensory input. Selection of the appropriate meaning is, therefore, mainly dependent on contextual information.[1] With respect to ambiguity resolution, lexical selection might thus be seen as a consequence of the successful integration of one meaning within the context, while the integration of the other meaning fails (cf. Rayner & Frazier, 1989). Because the analysis of the sensory input does not lead to a differential outcome in the case of ambiguous words, studying the resolution of lexical ambiguity is a preferred way of experimentally testing at what phase of lexical processing context has its influence. Moreover, it allows to track the time course with which contextual information is used to integrate and select the contextually appropriate meaning.[2]

The most relevant research for addressing these issues has used a cross-modal priming procedure (Swinney, Onifer, Prather, & Hirskowitz, 1979; Swinney, 1979).[3] Subjects are presented sentences containing an ambiguous word, and a target either related or unrelated to one of its meanings. The sentences are presented auditorily, while the targets are presented visually. Usually, the sentence biases one meaning of the ambiguous word, while the target is either related to the same meaning or to the alternative one. Targets unrelated to either meaning serve as the controls (for a slightly different design, see Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982, and Tanenhaus, Leiman, & Seidenberg, 1979). The time lag between the offset of the ambiguous word and the presentation of the visual target varies, with an inter-stimulus-interval (ISI) of zero msec as the shortest interval. Latencies of the subject's response to the targets related to either meaning of the ambiguity are compared to those on their unrelated controls.

In cross-modal priming studies on the resolution of lexical ambiguity, three different tasks have been used: lexical decision on the targets (Blutner & Sommer, 1988; Lucas, 1987; Onifer & Swinney, 1981; Simpson, 1981; Swinney, 1979; Tabossi, 1988; Tabossi, Colombo & Job, 1987; Tanenhaus & Donnenwerth-Nolan, 1984), naming of the target word (Seidenberg et al., 1982; Tanenhaus et al., 1979), or a Stroop task in which the color of the target word had to be named as quickly as possible (Conrad, 1974; Oden & Spira, 1983).

The most salient finding of these cross-modal priming studies is that initially (i.e., at an ISI of 0 msec) not only targets related to the contextually biased meaning, but also those related to the unbiased meaning are facilitated relative to their unrelated controls. With longer intervals between the ambiguous word and the target (i.e., 200 msec or longer), facilitation is only obtained for targets related to the contextually appropriate meaning (Onifer & Swinney, 1981; Seidenberg et al., 1982; Swinney, 1979; Tanenhaus et al., 1979). These results have been taken as support for an autonomous model of lexical access (Swinney, 1979; Tanenhaus et al., 1979). Independent of contextual constraints, all meanings of an ambiguous word are accessed. Contextual information is claimed to have its impact only in a post-perceptual stage of processing, by selecting the contextually appropriate meaning and suppressing the contextually inappropriate one. This suppression process is completed within 200 msec after the ambiguous word has been heard (Seidenberg et al., 1982).

However, this standard picture has to be qualified on the basis of studies indicating that these results can be modulated by the kind of context (Blutner & Sommer, 1988; Seidenberg et al., 1982; Tabossi, 1988; Tabossi et al., 1987), and by the role of the frequency of occurrence of each meaning (Rayner & Frazier, 1989; Simpson, 1981).

In one of their experiments, Seidenberg et al. (1982) constructed context sentences that in addition to the global bias in the direction of one meaning, contained a word with an associative and/or semantic relation to the biased reading of the ambiguous word. For this type of context they only obtained activation of the contextually appropriate meaning of ambiguous nouns, when probed at the offset of the ambiguity. The authors attributed the selective activation effect to lexical priming from the particular word in the context to the related meaning of the ambiguous noun.[4] They argue that for this reason the context effect should not be attributed to the top-down influence of the higher-level message representation on the initial access of the lexical meaning(s) of an ambiguous word. The locus of this type of context effect is claimed to be at the level of lexical representations, and consequently selective activation is a result of intra-lexical processing (cf. Forster, 1979). Lexical context effects can thus be seen as arising from the hardwiring of the mental lexicon. As such they are not an argument against autonomous models of lexical access.

The results obtained by Tabossi et al. (1987), and by Tabossi (1988) are more difficult to interpret in terms of automatic lexical access. Tabossi and her colleagues constructed sentential-semantic contexts that primed a specific feature of an ambiguous word. Take, for instance, the following sentence: "The violent hurricane did not damage the ships that were in the *port*, one of the best equipped along the coast". In this sentence the context up to the ambiguous noun *port* is suggested to prime the meaning aspect SAFE, a core feature of its dominant meaning.[5] In contexts where the dominant meaning of the ambiguous noun was biased for, no activation was seen for its subordinate, contextually inappropriate meaning, when probed at the offset of the ambiguous noun.

To explain the discrepancy between her results and the standard picture on the resolution of lexical ambiguity in a sentential-semantic context, Tabossi suggests that semantic feature priming is a very efficient mechanism to make a context highly constraining. This, then, would allow the context to have its effect on early stages of lexical processing. The selective activation in this type of context is claimed to support a model of selective lexical access, according to which a highly constraining context can affect the access phase (Tabossi et al., 1987).

This conclusion, however, does not necessarily follow from her results. Zwitserlood (1989) has shown for the recognition of unambiguous words that even though context does not influence lexical access, it can have its effect during the phase of lexical selection well before the end of the spoken word. Because the moment at which Tabossi picked up a selective context effect was at the end of the spoken ambiguity, it is possible that in her studies context had its effect not on lexical access, but on lexical selection.

On the basis of the current studies on ambiguity resolution, it is impossible to empirically decide between the alternatives of selective access and early selection. What one can conclude, though, from studies using different types of context is that the moment at which context affects lexical processing depends on the types of knowledge representations involved. However, in the absence of a sufficiently specified theory on the nature of message representations, it is difficult to determine exactly how different sentential contexts affect lexical processing (for a preliminary proposal, see Tanenhaus & Lucas, 1987).

The results obtained by Tabossi already alluded to the influence of the frequency of occurrence of the different meanings on the processing of lexical ambiguities. For most ambiguities, one reading is clearly dominant over the other. In the absence of (a biasing) context the dominant meaning is activated earlier than the subordinate meaning (Simpson & Burgess, 1985). The subordinate meaning seems to need more time to reach the required level of activation than the dominant meaning. After the initial access of the dominant and the subordinate meaning, normally the dominant one is retained and the subordinate one is suppressed within about half a second, provided that a biasing context is absent.

In a biasing sentence context, Onifer and Swinney (1981) obtained facilitation both for targets related to the dominant and targets related to the subordinate meaning of the ambiguity, independent of whether the sentence context biased the dominant or the subordinate reading. This result was taken by the authors as support for the claim that the meanings of ambiguous words are always accessed exhaustively, regardless of dominance and context.

Results with longer ISIs (e.g., Simpson, 1981) suggest that very rapid selection occurs for the dominant meaning. That is, if the context biases the dominant meaning, the subordinate meaning is suppressed very rapidly, within a time window of about 120 msec (Simpson, 1981). If, however, the subordinate meaning is biased by the context, suppression of the dominant meaning takes more time, provided that the contextual bias is relatively weak (Simpson, 1981).

Some studies (Tabossi, 1988; Tabossi et al., 1987; Rayner & Frazier, 1989) report results suggesting that in a sentence context which biases the dominant meaning, the subordinate meaning is not accessed at all. At first glance, these results seem to support an ordered access model (Hogaboam & Perfetti, 1975) in which it is assumed that regardless of context the dominant meaning is accessed first. Only when this meaning cannot be integrated with the context, does access of the subordinate meaning follow. However, the finding that selection of the contextually appropriate word candidate often occurs before the whole word has been processed (Zwitserlood, 1989), suggests an alternative interpretation for these results. In this interpretation, the convergence of contextual bias and meaning dominance leads to an almost instantaneous suppression of the contextually inappropriate, subordinate meaning of the ambiguous word; that is, this convergence leads to early selection.

A final remark should be made with respect to some methodological concerns about the cross-modal priming effects. These concerns have been raised after effects of associative backward priming (Koriat, 1981) and temporal backward priming (Kiger & Glass, 1983) were reported (cf. Glucksberg, Kreuz, & Rho, 1986; Van Petten & Kutas, 1987, 1988). The interpretation of priming effects is based on the assumption that they are a consequence of the forward spread of activation through the lexical network from an accessed meaning to a related target. The studies by Koriat (1981) and Kiger and Glass (1983) suggested that this assumption does not hold under all circumstances, and that facilitated lexical decisions can also be obtained with only backward (target-to-prime) associations (Koriat, 1981), or when the target is presented shortly before the prime (Kiger & Glass, 1983). This has caused uncertainty about the results of cross-modal ambiguity studies, because of the possibility that the findings supporting a multiple access view might be due to an artifact of the experimental procedure. However, recent studies have shown that in general the findings of multiple access in cross-modal ambiguity studies cannot be explained in terms of a backward spread of activation (Peterson & Simpson, 1989; see also Seidenberg, Waters, Sanders, & Langer, 1984).

Nevertheless, a few recent studies (Glucksberg et al., 1986; Van Petten & Kutas, 1987) have obtained effects that seem to support a selective access model. In order to eliminate potential backward priming effects, Glucksberg et al. (1986) used a nonword interference paradigm. With this paradigm they obtained selective interference for targets related to the contextually biased readings of ambiguous words. This result, however, is shown to be due to post-lexical processes (Burgess, Tanenhaus, & Seidenberg, 1989). The nonword interference methodology does not seem to be sensitive to lexical retrieval processes.

Post-lexical processes might also be responsible for the results of a recently reported study which recorded event-related brain potentials (ERPs) to targets following ambiguous words in a biasing sentence context (Van

Petten & Kutas, 1987). The ERP-component focused on in this study is the N400, which has been shown to be sensitive to semantic expectancy (e.g., Kutas & Hillyard, 1984). Van Petten and Kutas presented their sentences visually, one word at a time. The target followed the ambiguity with an SOA of 216 or 700 msec. At the short SOA, initially the waveform for the targets related to the contextually unbiased reading of the ambiguity did not differ from the waveform for the unrelated control targets. Only at about 500 msec after the target was presented, did the waveform for the targets related to the unbiased reading start to diverge from the waveform for the unrelated targets. The authors interpret these results as support for the backward priming account of multiple activation obtained in studies measuring lexical decision or naming latencies.

Recent research, however, casts serious doubts on the sensitivity of the N400 to automatic lexical retrieval processes. Brown, Hagoort, and Swaab (1989) and Neville (personal communication) failed to obtain N400-effects under conditions of masked priming, where they had found facilitation effects in a lexical decision task. Brown et al. interpret these results as indicating that the N400 is especially sensitive to post-lexical integration processes, but not to automatic lexical access processes.[6]

Both the Glucksberg et al. (1986) and the Van Petten and Kutas (1987) results, therefore, do not provide convincing evidence against multiple access of lexical ambiguities in a biasing sentence context. Moreover, evidence for the activation of multiple meanings has also been obtained in studies recording eye movements during reading (Rayner & Duffy, 1986; Rayner & Frazier, 1989). This methodology excludes any role of backward priming, because no target items are presented.

In conclusion, the overall picture emerging from the literature on the resolution of lexical ambiguity is that in a sentence context at least initially multiple meanings of ambiguous words are activated. This activation can be modulated by the frequency relation between the different meanings and by the contextual constraints. Both factors can influence the time course of the selection/integration process, resulting in the suppression of the contextually inappropriate meaning of an ambiguous word. Normally, the selection/integration process is completed within a very short time period of less than 200 msec after word offset. The subordinate meaning of the ambiguous word is, however, suppressed more rapidly than the dominant one. Moreover, in a context priming some salient aspects of one meaning of an ambiguous word, this meaning can be selected/integrated more rapidly than in a biasing context which does not prime specific features. Rapid selection is also possible when the context contains a word with a strong semantic/associative relation to one meaning of an ambiguous word. In all cases, however, lexical meanings are integrated within a very short time period into a higher-level message representation. This suggests that the on-line computation of a message representation requires the rapid availability of the contextually appropriate lexical meanings.

Sentential-semantic context effects on lexical processing in aphasia

The focus of this study is on the time course of ambiguity resolution in Broca's and Wernicke's aphasics. Do these patients show the same rapid integration of the contextually appropriate meaning of an ambiguous word and the concomitant suppression of the inappropriate meaning as obtains for the intact language comprehension system? A recent study by Swinney, Zurif, and Nicol (1989) indicates that at least for Broca's aphasics this might not be the case. Modelled after the Onifer and Swinney (1981) study, they presented ambiguous words in a biasing sentence context to four Broca's aphasics, four Wernicke's aphasics and four neurologically unimpaired control subjects. The ambiguous words had two readings that were strongly different in their frequencies of occurrence. Subjects had to make a lexical decision on visual targets presented at the offset of the ambiguous words. In contrast to the control subjects and the Wernicke's aphasics, the Broca's aphasics only showed facilitation for targets related to the dominant meaning of an ambiguous word, regardless of the contextual bias. So, even the context biasing the subordinate reading obtained selective facilitation for the target related to the dominant, contextually inappropriate reading.

One explanation given by the authors is that agrammatic patients fail in exhaustively accessing lexical items. From this explanation they derive the general hypothesis that these patients suffer from a failure to show exhaustive computation in any domain of cognition. However, because the authors did not vary the ISI between the ambiguous words and the visual targets, this explanation is by no means the only possible one, as they acknowledge. Another possibility they suggest is that the activation of lexical items shows a slower-than-normal rise time in Broca's aphasics. This would mean that eventually (i.e., at a longer ISI) facilitation should also be obtained for the subordinate meaning of ambiguous words.

This study pursues the second kind of explanation by investigating the resolution of lexical ambiguity with a short and a long ISI between ambiguity and target. The context either biases the dominant or the subordinate reading of an ambiguous word. If patients cannot exhaustively access the lexical data base, activation of the subordinate meaning should not be obtained under any circumstance. In that case, even at the long ISI only facilitation of the dominant targets will be seen.

The alternative option is that in agrammatic patients the temporal organization of the comprehension process has changed, causing a delay in the selection/integration process. This change might be due to a disturbance in the 'kinetic melody' (Von Monakow, 1914) of lexical access and contextual selection. A slower-than-normal lexical retrieval process or a slower-than-normal integration process (or a combination of both) can delay the selection of the contextually appropriate reading of an ambiguous word.

A slower-than-normal lexical access might selectively affect the subordinate meaning at a short ISI. Here, the dominant meaning is supposed to be already activated, whereas at the same time the subordinate meaning has not yet reached a critical level of activation. At a long ISI, however, the subordinate meaning is assumed to have had enough time to be fully retrieved. Thus in the case of a slower-than-normal lexical access, facilitation should only be obtained for the dominant target at the short ISI, regardless of the contextual bias. At the long ISI, however, enough time has passed for the delayed lexical retrieval process to be completed and for the context to select the appropriate reading. That is, the long ISI will obtain selective facilitation for the contextually appropriate reading of an ambiguous word, regardless of whether this is its dominant or its subordinate meaning.

If, however, the integration process is relatively delayed, then at the short ISI the aphasic patients are expected to show activation independent of the contextual bias for both the dominant and the subordinate meaning, whereas within the same time window the normal controls already selected the contextually appropriate meaning. At the long ISI, the slower-than-normal integration process is assumed to have had sufficient time for its completion. Thus at the long ISI the pattern of results should be the same for patient groups and normal controls, in that only activation of the contextually appropriate reading emerges.

To enable a test of these different predictions, the choice of the intervals between ambiguities and targets is critical. The short ISI in this study is 100 msec, the long ISI is 750 msec. With respect to the normal control subjects, the short ISI is supposed to be long enough for the context to select the biased reading, certainly when the bias is in the direction of the dominant meaning of an ambiguous word (cf. Simpson, 1981). The long ISI is assumed to be long enough for possibly delayed processes of lexical access and integration in aphasic patients to be completed. Recall that normally these processes are completed within at most 200 msec after the offset of an ambiguous word (Seidenberg et al., 1982).

Given the focus on the time course of contextual selection, the experiments do not directly test the issue of selective versus multiple access. However, the context sentences in this study deliberately do not contain words semantically or associatively related to a particular meaning of the ambiguity, nor do the sentences prime a salient feature of one of its meanings. Given these constraints on the materials, it is a reasonable assumption that the context sentences in this study do not prevent access to the unbiased meaning of the ambiguity. Thus, although the experiments do not directly test whether multiple access of both biased and unbiased meanings occurs, on the basis of our current knowledge on the processing of lexical ambiguities we can assume that this is the case.

In contrast to the Swinney et al. (1989) study, a cross-modal procedure is not used. Both the sentences and the targets are presented auditorily, and subjects are required to make a lexical decision on the auditory target. A cross-modal presentation is not critical for the issues addressed, since these concern a possible delay in contextual selection. To date, not enough is known about the possible complications of confronting aphasic patients with linguistic materials in two modalities at the same time. A cross-modal presentation requires the subjects to allocate their attention simultaneously to the visual and the auditory modality, and to integrate the linguistic information from both input modalities. Moreover, in the Swinney et al. study the aphasic patients had to read the target word. This reading process is much less under the experimenter's control than the process of listening to the target. In the latter case, the experimenter knows exactly how the sensory information is distributed over time, allowing a better estimation of the time frame in which the sensory input is processed. Therefore, I opted for a unimodal auditory presentation.

With respect to the subject groups, the following logic underlies the testing procedures. First of all, a group of younger subjects, mostly students, is tested. This allows a comparison of the results with previous studies on the processing of ambiguous words in a sentence context. The next step is to test the aphasic patients and a group of neurologically unimpaired normal controls who are matched in age and education with these patients. The results for the normal controls should show whether younger and older subjects have similar patterns of performance. Next, the results of the patient groups are compared with those of their control group. This three-step approach is seen as the best attainable strategy to determine abnormal patterns of performance in aphasic patients and to interpret these deviances in terms of our current knowledge about ambiguity resolution in a sentential-semantic context.[7]

Experiments 1a and 1b test the selection of the contextually appropriate reading at an ISI of 100 msec. Experiments 2a and 2b do the same at an ISI of 750 msec.

Experiment 1a

Method

Subjects
Thirty-six subjects from the subject pool of the Max Planck Institute for Psycholinguistics, most of them students at the University of Nijmegen, participated in this experiment. All subjects were native speakers of Dutch, and were paid for their participation.

Materials
Thirty-three noun-noun ambiguities with a dominant and a subordinate meaning were selected from a list of Dutch words with two or more unrelated meanings (see chapter 2). For each ambiguous noun a set of three context sentences with a relatively simple structure was constructed. Two of these context sentences contained an ambiguous noun as the sentence-final word. One sentence biased the dominant meaning, the other biased the subordinate meaning of the ambiguous noun. The third context sentence had an unambiguous noun as its final word. The unambiguous and the ambiguous noun were matched for length and frequency. The third context sentence served as the baseline for the two sentences with the ambiguous noun in sentence-final position. An example of the context triplets is given below (the sentence-final ambiguity and its control are in capitals; see note 9 for an English translation).

(1) *De schoonmaakster verwijderde de gemorste AS.*
(2) *De metaalarbeider laste de gebroken AS.*
(3) *De natuurvriend zag een zeldzame BIJ.*

All three context sentences had the same constituent structure. Syntactic information thus did not contribute to differential contextual constraints in the three sentences. This was done to ensure that differential context effects had to be attributed to only the semantic information of the sentences.

None of the content words in the sentences preceding the ambiguous noun were associatively related to the sentence-final noun (the prime) or to the target word presented after the sentence. This was checked against word association norms provided by De Groot (1980), and Van der Made van Bekkum (1973). In this way it was ensured that potential effects of contextual constraints could not be attributed to intra-lexical associative links between one or more words in the context and the prime or target (cf. Seidenberg et al., 1982). In general, the context sentences were constructed such that they did not prime a specific, salient feature of a particular meaning of the ambiguity (cf. Tabossi et al., 1987). Sentences were constructed with these two constraints in mind, to increase the likelihood that they allowed for the initial activation of both meanings of the ambiguity, regardless of the contextual bias.

Pretests

The set of 99 sentences (3 x 33) was submitted to a number of pretests. First of all a cloze test was performed. To avoid pre-selection of the contextually appropriate meaning by guessing the final word in the sentence, the preceding context should not make the predictability of the sentence-final noun too high. A first version of the cloze test contained the 99 sentences in a random order with the final word omitted. This cloze test was given to twenty-eight subjects from the MPI subject pool, who were paid for their participation. Subjects were instructed to complete the sentences by filling in one word that fitted the context. The results of the cloze test led to a revision of problematic items. Revised items were tested in a second cloze test on sixteen subjects, and a subset after further revision in a third cloze test on thirteen subjects.

In addition to this series of cloze tests an association test was performed on the material. In this test the complete context sentences were presented to the subjects. Subjects were required to read the sentences and to write down the first word that came to mind upon reading the final word of the sentence. With respect to the sentences ending with an ambiguous noun, this test established whether the context was successful in biasing the intended reading of the sentence-final ambiguity. For the sentences ending with an unambiguous noun, the results should confirm that this context was a proper control, in that the target word was never given as a response. Two versions of the association test were constructed. The two of the three context sentences ending with the same ambiguous noun were always assigned to different versions. In this way subjects were confronted with the ambiguous noun in one context only. The 33 control contexts were divided over the two versions. Each version of the association test was given to twenty subjects from the MPI subject pool. Subjects were paid for their participation.

The selected material

The series of pretests resulted in the selection of 24 ambiguous nouns with their respective context sentences that fitted the following criteria: (a) the cloze probability of the sentence-final noun (i.e., the ambiguous word or its control) did not exceed .45; (b) in the biasing context sentences at least 60% of the responses on the association test was related to the intended reading of the ambiguous noun, and at most 20% of the responses was related to the unintended reading. The selected context sentences had a mean length of 8 words (range: 6-12).

The target words for this study were selected from an association test that was done in the context of a previous experiment (see chapter 2). In this test associates were collected to a list of Dutch words with multiple meanings.

For 12 of the 24 ambiguous words in the present study, the highest associate of the dominant meaning was selected as target. These target words were combined with the sentence triplets to form the set of dominant items. The dominant meanings of the ambiguous nouns in this set of items had an average frequency of occurrence of 81% (range: 66-99).[8]

For the remaining 12 ambiguities, the highest associate of the subordinate meaning was chosen as target. Paired with the triplets of context sentences they made up the set of subordinate items. The average frequency of occurrence for the subordinate meaning of these 12 ambiguous nouns was 15% (range: 4-31).

TABLE 1

Examples of the sentences and target words in each condition. The sentence-final primes and the target words are in capitals.

Context Condition	Sentence	Target Word
	Target Type: Dominant	
Concordant:	*De schoonmaakster verwijderde de gemorste AS.*	*ROOK*
Discordant:	*De metaalarbeider laste de gebroken AS.*	*ROOK*
Unrelated:	*De natuurvriend zag een zeldzame BIJ.*	*ROOK*
	Target Type: Subordinate	
Concordant:	*De winnaar speelde tenslotte zijn AAS.*	*KAART*
Discordant:	*Het jongetje bevestigde tenslotte zijn AAS.*	*KAART*
Unrelated:	*De klant kocht uiteindelijk het BED.*	*KAART*

Crossing the target words with the sentences resulted in three context conditions. The concordant context biased the target-related reading of the ambiguity. The discordant context biased the alternative reading of the ambiguity. Finally, in the unrelated context condition, the sentence-final word and the target were in no way related. Examples of the sentence-target combinations are presented in Table 1.[9] The full set of critical word target items is given in Appendix 3.

For the set of dominant items, the concordant context biased the dominant meaning and the discordant context biased the subordinate meaning of the ambiguous noun. For the set of subordinate items, it was just the other way around: the concordant sentences biased the subordinate meaning of the ambiguities, while the discordant sentences biased the dominant meaning.

The results on the cloze test revealed that the mean cloze probabilities for the sentence-final nouns in the sets of dominant and subordinate items were less than 10%. None of the target words was given as a response in the cloze test.

The strength of the contextual bias for the selected sentences was computed from the results of the association test. For the dominant items, on average 81% of the responses to the concordant context sentences was related to the intended, dominant meaning, and 3% to the non-intended, subordinate meaning.[10] For the discordant context sentences a mean of 82% was related to the intended, subordinate meaning, and on average 9% to the non-intended, dominant meaning. The contextual bias for the set of subordinate target items was as follows: on average 77% of the responses to the concordant context sentences was in the direction of the intended, subordinate meaning, whereas 11% of the responses was related to the non-intended, dominant meaning; 87% of the responses to the discordant context sentences was in the direction of the intended, dominant meaning, and 3% was related to the non-intended, subordinate meaning. Taking the difference in frequency of occurrence (dominance) between both readings of the ambiguous nouns into account, these results indicate that the biases of the context sentences in the concordant and discordant conditions were not only in the intended direction, but were also comparable in strength. Finally, the target word was never given as a response in the unrelated control sentences.

In addition to the 24 target words preceded by three context sentences, 24 nonwords items were constructed consisting of a nonword target that was also preceded by three context sentences. For 12 of the nonword targets, two of the three context sentences had the same ambiguous noun in sentence-final position. These context sentences biased the two alternative readings of the ambiguity. The third context sentence ended in an unambiguous noun. An example of these nonword items is given below (the sentence-final ambiguity and its control, and the nonword target are in capitals).

De japon zit te wijd om haar MIDDEL.	*AZOE*
Tegen de muggen helpt geen enkel MIDDEL.	*AZOE*
De wesp viel bij mijn zusje in de SOEP.	*AZOE*

For the remaining 12 nonword targets, the three context sentences all ended in different unambiguous nouns. The construction of nonword items according to this procedure should prevent possible strategies in which the subject predicts the lexical status of the target (i.e., word/nonword) on the basis of sentence-final ambiguities.

In addition to the critical word items and the nonword items, 72 filler items and 24 startup items were constructed. Half of the filler items consisted of a word target preceded by an unrelated context sentence. The other half consisted of a nonword target preceded by a context sentence. The startup items also had an equal distribution of word and nonword targets.

The 240 stimulus sentences (3x24 Test, 3x24 Nonword-control, 72 Fillers, 24 Startup) were divided into three blocks, each containing 80 sentences. The three context sentences constructed for each of the 24 ambiguous nouns in the set of test items, were distributed among the three blocks such that each block contained 4 exemplars of each context type for both dominant and subordinate targets. Thus the three context conditions and the two target types were equally represented across blocks. However, target words and ambiguous nouns never occurred more than once per block. For the set of 24 nonword targets, the three context sentences were also evenly distributed among the blocks. The 72 filler items were assigned to the three blocks such that each block contained 12 filler sentences with a word target and 12 with a nonword target. The order of the sentences within a block was randomized. Each block started with 8 startup items, 4 with a word target and 4 with a nonword target. Thus each block consisted of 40 sentences with a word target and 40 sentences with a nonword target. The order of blocks was counterbalanced, resulting in three presentation versions.

In addition to the 240 sentences in the three experimental blocks, 32 practice items were constructed, partly from the set of sentences that did not meet the selection criteria for the critical test items. Half of the sentences were followed by a word, half by a nonword.

All materials were spoken at a normal rate by a female speaker in a sound-proof booth. The stimuli were digitized with a sampling frequency of 20 kHz, and stored in a VAX 750 computer. A speech waveform editing system was used to add targets to their respective sentences. Identical targets were represented by the same physical token. A trigger pulse was placed concurrent with target onset, and a warning signal preceded each sentence. The interval of silence (ISI) between sentence offset and target onset was 100 msec. Sentence-target pairs were separated by a 4-sec interval: 2800 msec of silence, a 200 msec warning signal, followed by another 1000 msec of silence. Four test tapes were constructed. One tape contained the practice items, each of the other tapes contained one of the three experimental blocks. The input to and the output from the computer were low-pass filtered with a cutoff frequency of 10 kHz.

Apparatus
The apparatus for the experiment consisted of a Revox B77 stereo tape recorder, a Miro GD laboratory computer, a pulse-read unit, two pairs of Sennheiser HD 224 closed headphones (one for the subject and another for the experimenter), and a response keyboard with a YES and a NO button. The stimuli on the left channel of the tape were played binaurally to the subjects, while the trigger pulses on the right channel of the tape started a millisecond timer. The pulses were inaudible to the subjects. Reaction times and type of response (yes/no) were stored directly with the aid of the computer. The time-out was set to 3 seconds. Latencies longer than 3 seconds were automatically stored as missing values.

Procedure
Subjects were assigned randomly to one of the three presentation versions, with twelve subjects in each version. The subjects were tested individually in a single session, lasting approximately 40 minutes. Subjects were seated in a sound-proof booth with the keyboard placed in front of them, pressing the YES button with the index finger of the dominant hand and the NO button with the other index finger.

Subjects were told that they would hear a series of sentences immediately followed by a real Dutch word or a nonword. They were instructed to listen to each sentence, and to respond to the following sound sequence as quickly as possible, indicating whether it was a word by pressing the YES button or a nonword by pressing the NO button. To make sure that the subjects listened to the sentences, they were told that a number of questions on the content of the sentences would be asked at the end of the session. They were advised to pay close attention to the sentences but not to actually memorize them. The subjects were then presented with the 32 practice trials. Before the three blocks of test trials were presented, slow subjects were asked to increase the speed of responding without losing accuracy. No further feedback was given during the test session. At the end of the test session subjects were asked a few questions about the materials.

Results

For the analyses of variance, the six sentence-target conditions were divided into two factors: Target Type with two levels, and Congruency with three levels. Target Type referred to whether the target was related to the dominant or to the subordinate meaning of the ambiguity. Congruency referred to whether the sentence was concordant, discordant, or unrelated with respect to the reading of the ambiguous noun that was probed by the target.

Analyses were done on latency data and error data of the critical word target trials. Before the analyses on the latency data, errors and missing values (due to mechanical failures and time-outs) were replaced by the subject's median latency in the relevant condition. In all cases, separate Repeated Measures Analyses of Variance were performed, treating subjects and items (target words) as random factors. In the subject analysis, Subjects, Target Type, and Congruency were completely crossed. In the item analysis, Items were nested within Target Type, but crossed with Congruency. Analyses of the latency data were performed on the subject medians (in the subject analysis) or the target word medians (in the item analysis) for each condition.[11] Analyses of the error data were done on the numbers of errors per condition. In the following, the results of the subject analyses will be reported. Results of the item analyses will only be reported if effects which are significant in the subject analysis, are not significant in the item analysis (i.e., they have a value of $p>.10$). In this case, the two analyses yield different results. Nonorthogonal planned pairwise comparisons tested the differences between the three context conditions (Winer, 1971).

Latency analyses

Means of the subject median latencies in the three context conditions are presented in Table 2. An overall ANOVA was performed on lexical decision times for all six sentence-target conditions. The analysis revealed a significant main effect of Target Type ($F(1,35)=136.03$, $MSe=1155$, $p<.0001$). Subjects' responses to the dominant targets were on average 54 msec faster than those to the subordinate targets. This effect is mainly attributable to a difference in length between the dominant and the subordinate targets. The dominant targets had a mean length of 574 msec (range: 453-671), and were on average 39 msec shorter than the subordinate targets, which had a mean length of 613 msec (range: 490-893). The remaining difference might be due to idiosyncratic aspects of the sets of dominant and subordinate targets. These, however, do not have implications for the interpretation of the results with respect to the role of context in the resolution of lexical ambiguity. With respect to this interpretation, the

TABLE 2

Means (both across and by Target Type) of the median auditory lexical decision times as a function of Context Condition (ISI=100 msec).

ISI=100 msec	Overall		Dominant		Subordinate	
Context Condition	RT	d	RT	d	RT	d
	Students (N=36)					
Concordant	617	66	604	55	631	76
Discordant	667	16	623	36	711	−4
Unrelated	683		659		707	

Differences (d) are measured relative to the unrelated baseline.

differential effects of the concordant and discordant priming conditions relative to the unrelated baseline are most critical, not the absolute values of the reaction times.

A significant main effect was also obtained for Congruency ($F(2,70)=47.14$, $MSe=1777$, $p<.0001$). Lexical decision latencies were shorter in the concordant context relative to both the discordant and the unrelated context. The main effect of Congruency was, however, qualified by a significant Target Type by Congruency interaction ($F(2,70)=20.11$, $MSe=854$, $p<.0001$). Inspection of Table 2 shows that the discordant context acted differently for the dominant and the subordinate targets. Separate ANOVAs were, therefore, performed on the data of both target types.

The analysis for the set of dominant target items showed a significant effect of Congruency ($F(2,70)=18.66$, $MSe=1490$, $p<.0001$). The differences between the three context conditions were tested by means of nonorthogonal planned comparisons.[12] The planned comparisons showed that all three differences were significant. Relative to the unrelated context, facilitation emerged for the dominant targets not only in the concordant context ($F(1,35)=27.56$, $p<.0001$), but also in the discordant context ($F(1,35)=16.87$, $p<.0005$). Finally, the 19 msec difference between the concordant and the discordant context was also significant ($F(1,35)=5.70$, $p<.05$).

A simple main effect of Congruency was also obtained for the set of subordinate target items ($F(2,70)=64.08$, $MSe=1142$, $p<.0001$). Planned comparisons showed significant facilitation for the subordinate targets in the concordant context relative to both the unrelated context ($F(1,35)=79.73$, $p<.0001$) and the discordant context ($F(1,35)=87.71$, $p<.0001$). No facilitation emerged for the subordinate targets in the discordant context relative to the unrelated baseline ($F<1$).

In summary, both target types showed facilitation in the concordant context relative to the other two context types. The two target types differed from each other in the facilitation obtained in the discordant context. In this context facilitation relative to the unrelated context only emerged for the dominant targets, not for the subordinate ones.

Error analyses

Subjects' mean percentages of errors for each sentence-target condition are presented in Table 3. Errors were made on 2.8% of the trials with critical word targets. Error data showed an overall pattern of results comparable to that of the latency data. That is, the least number of errors was made in the context biasing the appropriate reading of the ambiguous noun, and the highest was made in the unrelated context.

TABLE 3

Mean percentage of errors (and total number of errors), across and by Target Type, as a function of Context Condition (ISI=100 msec).

ISI=100 msec	Overall	Dominant	Subordinate
Context Condition			
	Students (N=36)		
Concordant	1.3 (11)	0.5 (2)	2.1 (9)
Discordant	2.8 (24)	1.9 (8)	3.7 (16)
Unrelated	4.3 (37)	3.7 (16)	4.9 (21)

An overall ANOVA was performed on the number of errors for the six sentence-target conditions. The analysis yielded a significant effect of Target Type ($F(1,35)=7.35$, $MSe=0.25$, $p=.01$), which however did not approach significance in the item analysis ($p=.28$). A significant main effect of Congruency was also obtained ($F(2,70)=8.23$, $MSe=0.29$, $p<.001$). Most errors were made in the unrelated context, and least errors occurred in the concordant context. The Target Type by Congruency interaction was not significant ($F<1$).

Planned comparisons demonstrated that significantly less errors were made to the dominant targets in the concordant context compared to the unrelated context ($F(1,35)=10.27$, $p<.005$). The difference between the number of errors for the dominant targets in the discordant and the unrelated condition was only marginally significant ($F(1,35)=3.08$, $p=.09$), as was the difference between the concordant and the discordant condition ($F(1,35)=3.89$, $p=.06$).

For the subordinate targets, planned comparisons only yielded a significant difference between the concordant and the unrelated condition ($F(1,35)=5.38$, $p<.05$). The number of errors made in the discordant context was not significantly less than that in the unrelated baseline ($F(1,35)=1.00$, $p=.32$).

In sum, the pattern of results for the error data was in agreement with the picture emerging from the latency data. Evidence for a speed-accuracy trade-off was absent.

All subjects were aware that some targets were repeated, and some subjects reported being aware of the presence of ambiguous words. To check whether the repetition of targets and ambiguous words might have induced subjects to use special strategies, analyses were performed on the data from the block that was first presented to the subjects. Recall that within a block, targets and ambiguous words were never repeated. Each of the three blocks occurred first in one of the three presentation versions. Consequently, all of the items used in the experiment were included in the first-block analyses. The results of these analyses closely match the overall analyses.

A first-block ANOVA on the latency data yielded significant main effects of Target Type ($F(1,35)=39.43$, $MSe=5054$, $p<.0001$) and of Congruency ($F(2,70)=18.50$, $MSe=5803$, $p<.0001$). Lexical decision latencies were on average 61 msec longer for the subordinate targets than for the dominant targets. The Target Type by Congruency interaction failed to reach significance ($F(2,70)=2.29$, $MSe=4639$, $p=.11$). Planned comparisons showed essentially the same pattern of differences between the three sentence types as was obtained in the overall analyses.

For the dominant targets, significant facilitation was obtained relative to the unrelated context, both in the concordant context ($F(1,35)=10.84$, $p<.005$) and in the discordant context ($F(1,35)=5.90$, $p<.05$). Although the difference between the concordant and the discordant condition was practically the same as in the overall analysis (23 msec in the first-block analysis, and 19 msec in the overall analysis), a planned comparison showed that it was only marginally significant ($F(1,35)=3.13$, $p=.09$).

Planned comparisons yielded significant facilitation for the subordinate targets in the concordant context only, relative to both the unrelated baseline ($F(1,35)=26.70$, $p<.0001$) and the discordant context ($F(1,35)=22.70$, $p<.0001$). Latencies in the discordant context were not significantly different from those in the unrelated context ($F<1$).

The results for the first-block analysis on the error data also closely corresponded to the results of the overall analysis. The effect of Congruency was the only significant main effect ($F(2,70)=5.29$, $MSe=0.14$, $p<.01$). Although more errors were made to subordinate target items than to dominant target items (5.1% vs. 3.3%), the effect of Target Type failed to attain significance ($F(1,35)=2.20$, $MSe=0.14$, $p=.15$). The Target Type by Congruency interaction was not significant either ($F<1$).

Planned comparisons for the dominant targets revealed that significantly more errors were made in the unrelated than in the concordant condition ($F(1,35)=11.67$, $p<.005$). The difference between the concordant and the discordant condition was also significant ($F(1,35)=5.65$, $p<.05$), with more errors in the discordant condition, but the discordant condition did not differ significantly from the unrelated one ($F(1,35)=1.35$, $p=.25$).

Although the subordinate targets showed the least number of errors in the concordant condition, neither the difference with the unrelated baseline ($F(1,35)=1.98$, $p=.17$), nor the difference with the discordant condition ($F(1,35)=2.36$, $p=.13$) approached significance. Moreover, the number of errors in the discordant context did not differ from that in the unrelated context ($F<1$).

Since the pattern of results for the first-block analyses is highly similar to the one in the overall analyses (although the statistics are weaker as one would expect), it seems unlikely that the results obtained were influenced by the repetition of targets and ambiguous words.[13]

Discussion

The findings of this experiment support the view that both context and dominance play an important role in the resolution of lexical ambiguity. Shortly after the ambiguous noun has been encountered, activation of its subordinate reading is only seen in a context biasing this reading, while no activation is obtained for the subordinate reading in a context that biases the dominant interpretation of the ambiguity.

In contrast, the dominant reading is always activated, irrespective of the contextual bias. Nevertheless, even here the effect of context is clear in that the amount of activation for the dominant reading is larger in the congruent context than in the incongruent context.

These results can be interpreted both in terms of an ordered access model (e.g., Hogaboam & Perfetti, 1975), and of an exhaustive access model (e.g., Onifer & Swinney, 1981). According to the ordered access model, the dominant meaning is always retrieved first. If it can be integrated into the context, the activation of other, subordinate meanings of the ambiguous word will not occur. So, this model predicts that regardless of context, activation of the dominant meaning will always occur. Activation of the subordinate meaning, however, only arises in a context in which the subordinate interpretation of the ambiguity is appropriate. These predictions are in agreement with the findings of the experiment. Recall, however, that the activation of the ambiguity's meanings was not probed immediately after the ambiguous noun, but with a delay of 100 msec. Therefore, the results cannot be taken as decisive evidence against an exhaustive access model.

According to the exhaustive access model, both dominant and subordinate meanings of an ambiguous word are accessed, irrespective of the contextual bias (Lucas, 1987; Onifer & Swinney, 1981). Contextual constraints are then used to rapidly select the contextually appropriate reading and to suppress the inappropriate one. The exhaustive access model would put forward the following interpretation of the data. By the time the activation of the dominant and subordinate meanings of an ambiguous noun were probed in this experiment, suppression of the inappropriate, subordinate meaning had been completed. The dominant meaning, however, was still partly activated in the discordant context that biased the subordinate reading of the ambiguity. This could be for two reasons. First, suppressing the dominant reading might take more time than suppressing the subordinate reading (cf. Simpson & Burgess, 1985). In that case, activation of the dominant meaning in a discordant context should no longer emerge with increased intervals between ambiguous noun and target. Second, in constructing the context sentences, care was taken to avoid the types of contexts for which selective access effects have been claimed (Seidenberg et al., 1982; Tabossi, 1988; Tabossi et al., 1987). This, one could argue, resulted in context sentences that although effective in their bias, did not contain very strong semantic constraints, which might be necessary for suppressing the dominant meaning completely. As a result, some activation of the dominant meaning will remain, even at longer ISIs.

Although the results can be accounted for in terms of both ordered access and exhaustive access models, it nevertheless seems warranted to conclude that with the ISI of 100 msec the selection/integration process has been completed for the dominant reading, and is under way for the subordinate reading. Given the focus on the time course of meaning selection in the present study, this seems to be the most relevant aspect of the findings of this experiment.

Experiment 1b

Experiment 1a served the purpose of establishing the interpretative framework for Experiment 1b in which a group of Broca's aphasics, a group of Wernicke's aphasics and a group of neurologically unimpaired control subjects are tested with the same materials. The control subjects are expected to show essentially the same pattern of results as the younger subjects in Experiment 1a.

The following predictions can be made for the aphasic patients. If the selection of contextually appropriate lexical meanings is relatively delayed in aphasic patients, the activation of the ambiguity in the concordant context will not differ from its activation in the discordant context. If, on the other hand, aphasic patients only access the dominant meaning of an ambiguity, as has been claimed for the Broca's aphasics (Swinney et al., 1989), facilitation will be obtained for the dominant but not for the subordinate targets, irrespective of the contextual bias.

Method

Subjects
Twelve aphasic patients and twelve normal control subjects participated in this experiment. All patients and neurologically unimpaired control subjects were right-handed. Patients were diagnosed on the basis of both their AAT-results and the rating of a spontaneous speech sample by three staff members of the Aphasia Project at the Max Planck Institute. Nine patients were unanimously diagnosed as Broca's aphasics. Three patients were unanimously classified as Wernicke's aphasics. Patients' age, gender, results on the Token Test, and their scores on the AAT-subtest on comprehension are specified in Table 4.

All patients had a CVA in the left hemisphere. At time of testing the mean post onset was 7 years (range: 2-16). The normal control subjects were approximately matched in age and education with the aphasic patients. The mean age of the aphasic patients was 58 years (range: 25-77), and the mean age of the normal control subjects was 59 years (range: 51-73).

Materials and apparatus
The test tapes from Experiment 1a were also used with the normal control subjects and the aphasic patients. The same apparatus was used as in Experiment 1a.

TABLE 4

Patient information

Patient	Age	Sex	Token Test*	Comprehension** Score AAT	Audit. Compr. Score AAT
01 Broca	59	m	2	93/120	51/60
02 Broca	49	m	42	86/120	39/60
03 Broca	55	m	37	73/120	43/60
04 Broca	25	m	34	100/120	54/60
05 Broca	63	m	24	76/120	42/60
06 Broca	60	f	9	98/120	47/60
07 Broca	35	f	31	85/120	49/60
08 Broca	71	m	8	102/120	54/60
09 Broca	61	m	21	102/120	51/60
10 Wernicke	73	m	25	59/120	41/60
11 Wernicke	65	m	19	82/120	36/60
12 Wernicke	77	m	32	83/120	31/60

* Scores on the Token Test are corrected for age. Severity of the disorder as indicated by the Token Test: no disorder (0-3); light (4-10); middle (11-33); severe (>33).

** Severity of the comprehension disorder as indicated by the AAT subtest Comprehension (includes word and sentence comprehension in both auditory and visual modality): severe (0-59); middle (60-89); light (90-104); no disorder (105-120).

Ranges of severity are based on the norms for the German version of the AAT.

Procedure

The twelve normal control subjects, the nine Broca's aphasics and the three Wernicke patients were assigned randomly to the three presentation versions. Four control subjects, three Broca's aphasics and one Wernicke patient were assigned to each of the three versions. The subjects were tested in a single session of approximately one hour, including short three minute breaks before the experimental blocks and a longer ten minute break after the first tape with test trials. Subjects were seated in a quiet room diagonally across from the experimenter, with the keyboard placed in front of them.

Subjects were given similar instructions as above, albeit in a less standardized form. In addition, they were told that during the test session the tape would be stopped on a number of occasions and a question would be asked about the preceding sentence. This was done to be sure that the subjects listened to the sentences. On average five times per block the tape was stopped at the end of a trial and the subject had to answer a question about the content of the sentence. Questions were never asked on trials immediately preceding a critical sentence-target pair.

After the instruction the practice trials were presented to familiarize the subjects with the procedure. If necessary, the instruction was given again and the practice trials were repeated. Before the presentation of the three blocks of test trials, the experimenter again emphasized the importance of both speed and accuracy. No further feedback was given during the test session.

The response procedure validated in a previous set of experiments (see chapter 3) was also used in this experiment. That is, the normal control subjects and the patients with complete control of both hands were instructed to place their left index finger on the YES button at the left side of the keyboard, and their right index finger on the NO button at the right side of the keyboard. Aphasic patients with control of their left hand only, were required to place their left index finger on the YES button. They were instructed to press the YES button when they heard a word, and to move their finger to the NO button and press it when they heard a nonword.

Results

Replacement of errors and missing values (due to mechanical failures and time-outs), and the analyses of variance on the latency and the error data were done according to the same procedures as in Experiment 1a. The data from the three subject groups in this experiment were submitted to independent ANOVAs. Since the repetition of targets and ambiguous words has been shown not to influence the pattern of results, only overall ANOVAs will be reported.

Latency analyses
Table 5 presents a summary of the latency data for the normal control subjects and for both groups of aphasic patients. For the group of normal control subjects an overall ANOVA yielded significant main effects of Target Type ($F(1,11)=36.28$, $MSe=2218$, $p=.0001$) and of Congruency ($F(2,22)=17.40$, $MSe=1030$, $p<.0001$). Latencies were on average 67 msec longer for the subordinate targets. Although inspection of the data suggests that the discordant context might behave differently for the dominant and the subordinate targets, the Target Type by Congruency interaction failed to reach significance ($F(2,22)=2.30$, $MSe=1315$, $p=.12$). Planned

TABLE 5

Means (both across and by Target Type) of the median auditory lexical decision times as a function of Context Condition (ISI=100 msec).

ISI=100 msec	Overall		Dominant		Subordinate	
Context Condition	RT	d	RT	d	RT	d
	Normal Controls (N=12)					
Concordant	767	54	736	61	797	48
Discordant	802	19	756	41	847	−2
Unrelated	821		797		845	
	Broca's Aphasics (N=9)					
Concordant	928	80	895	78	961	82
Discordant	942	66	899	74	984	59
Unrelated	1008		973		1043	
	Wernicke's Aphasics (N=3)					
Concordant	991	53	916	122	1066	−16
Discordant	1012	32	1043	−5	982	68
Unrelated	1044		1038		1050	

Differences (d) are measured relative to the unrelated baseline.

comparisons testing the overall differences between the three context types, showed significant differences between the concordant context and the other two context conditions (relative to the unrelated context: $F(1,11)=78.19$, $p<.0001$; relative to the discordant context: $F(1,11)=10.41$, $p<.01$). The 19 msec difference between the discordant and the unrelated context was marginally significant ($F(1,11)=3.51$, $p=.09$). However, this latter difference had to be fully attributed to the effect of the discordant condition on the dominant targets.

Planned comparisons revealed that for the dominant targets, facilitation was obtained relative to the unrelated baseline in both the concordant context ($F(1,11)=19.25$, $p<.005$) and the discordant context ($F(1,11)=9.99$, $p<.01$). The 20 msec difference between the concordant and the discordant condition, however, did not approach significance (F(1,11)=1.71, p=.22).

For the targets related to the subordinate reading of the ambiguities, planned comparisons yielded significantly faster lexical decisions in the concordant context, relative to both the unrelated context (F(1,11)=17.45, p<.005) and the discordant context (F(1,11)=10.61, p<.01). No facilitation emerged for the subordinate targets in the discordant context relative to the unrelated baseline (F<1).

In summary, the normal control subjects showed facilitation for the dominant targets irrespective of the contextual bias, and facilitation for the subordinate targets only in a context which biased the subordinate reading of the ambiguous nouns.

An ANOVA on the latency data of the Broca's aphasics showed significant effects of Target Type (F(1,8)=11.93, MSe=5135, p<.01; but not significant in the item analysis: p=.16), and Congruency (F(2,16)=6.89, MSe=4796, p<.01). Subjects' response latencies were on average 74 msec longer for the subordinate targets. No significant Target Type by Congruency interaction was obtained (F<1). Planned comparisons testing the overall differences between the three context conditions, yielded significant facilitation for the concordant context (F(1,8)=13.00, p<.01), but also for the discordant context (F(1,8)=6.27, p<.05), relative to the unrelated baseline. In contrast to the normal controls, however, the Broca's aphasics did not show a significant difference between the concordant and the discordant condition (F<1).

Planned comparisons for the dominant and subordinate targets confirmed the overall pattern of results. The dominant targets showed facilitation relative to the unrelated context in both the concordant context (F(1,8)=5.40, p<.05) and the discordant context, although the latter effect was only marginally significant (F(1,8)=4.37, p=.07).

For the subordinate targets, planned comparisons only yielded a significant difference between the concordant context and the unrelated baseline (F(1,8)=15.03, p<.005). The difference between the discordant condition and the unrelated baseline failed to reach significance (F(1,8)=2.16, p=.18). Contrary to the results for the control group, the Broca's aphasics did not show facilitation in the concordant context relative to the discordant context (F<1).

In summary, the Broca's aphasics showed facilitation for the dominant targets, irrespective of the contextual bias. The same picture seemed to emerge for the subordinate targets, although the facilitation for the incongruent context failed to reach significance.

The restricted number of Wernicke's aphasics substantially reduced the power of the F-test. The results for this group should therefore be interpreted with extreme caution. The ANOVA on the lexical decision times of the Wernicke's aphasics did not yield significant effects of Target Type ($F(1,2)=2.97$, $MSe=1716$, $p=.23$) or Congruency ($F<1$). The Target Type by Congruency interaction was not significant either ($F(2,4)=2.46$, $MSe=7001$, $p=.20$). None of the planned comparisons yielded a significant effect. Although the dominant targets showed a facilitatory trend (122 msec) in the context that biased the dominant reading of the ambiguity, a planned comparison revealed that this difference was only marginally significant ($F(1,2)=8.60$, $p=.10$). The curious facilitatory trend for the subordinate targets in the discordant context relative to the concordant context, was not significant ($F(1,2)=5.01$, $p=.15$).

In summary, despite some trends in the data, no significant context effects were obtained for the Wernicke's aphasics, neither for the dominant nor for the subordinate targets.

Error analyses

The error data of the three subject groups in Experiment 1b are summarized in Table 6. The normal control subjects gave a nonword response to the critical word targets in 2.1% of the cases. An overall ANOVA on the error data of the control subjects yielded a significant effect of Congruency ($F(2,22)=9.95$, $MSe=0.08$, $p<.001$). Most errors were made in the unrelated condition. Neither the effect of Target Type, nor the Target Type by Congruency interaction approached significance (both $Fs<1$). Planned comparisons testing the overall differences between the number of errors in the three context types, revealed that significantly more errors were made in the unrelated condition compared to both the concordant ($F(1,11)=12.57$, $p<.005$) and the discordant condition ($F(1,11)=15.40$, $p<.005$). For the dominant targets, only the planned comparison of the error scores in the concordant and the unrelated context yielded a significant difference ($F(1,11)=7.86$, $p<.05$). Planned comparisons for the subordinate targets revealed that only the difference between the discordant and the unrelated context was significant ($F(1,11)=5.50$, $p<.05$). In conclusion, the results for the error data in no way contradict the pattern of results obtained for the lexical decision latencies. No speed-accuracy trade-off was obtained.

The Broca's aphasics made errors on 4.9% of the critical word target trials. Most errors were made in the unrelated context. An ANOVA on the error data of the Broca's aphasics yielded a significant effect of Congruency ($F(2,16)=4.36$, $MSe=0.54$, $p<.05$). The effect of Target Type failed to approach significance ($F(1,8)=1.84$, $MSe=0.64$, $p=.21$). The Target Type by Congruency interaction was not significant either ($F(2,16)=1.66$, $MSe=0.34$, $p=.22$). Planned comparisons testing the overall differences between the three sentence types, revealed a significant difference between the concordant and the unrelated context ($F(1,8)=7.43$, $p<.05$). The other

TABLE 6

Mean percentage of errors (and total number of errors), across and by Target Type, as a function of Context Condition (ISI=100 msec).

ISI=100 msec	Overall	Dominant	Subordinate
Context Condition			
	Normal Controls (N=12)		
Concordant	1.0 (3)	0.0 (0)	2.1 (3)
Discordant	1.4 (4)	1.4 (2)	1.4 (2)
Unrelated	3.8 (11)	3.5 (5)	4.2 (6)
	Broca's Aphasics (N=9)		
Concordant	1.9 (4)	0.0 (0)	3.7 (4)
Discordant	5.1 (11)	2.8 (3)	7.4 (8)
Unrelated	7.9 (17)	8.3 (9)	7.4 (8)
	Wernicke's Aphasics (N=3)		
Concordant	6.9 (5)	8.3 (3)	5.6 (2)
Discordant	11.1 (8)	5.6 (2)	16.7 (6)
Unrelated	11.1 (8)	11.1 (4)	11.1 (4)

Differences (d) are measured relative to the unrelated baseline.

two comparisons failed to reach significance. For the dominant targets, only the difference between the concordant and the unrelated context was shown to be significant in a planned comparison ($F(1,8)=7.20$, $p<.05$). None of the planned comparisons for the subordinate targets approached significance. Thus, the error data correspond with the latency data, in that no significant differences between the congruent and the incongruent context were obtained for both dominant and subordinate targets.

The Wernicke's aphasic had an overall error score of 9.7% on the critical word target trials, clearly higher than the other two subject groups. An ANOVA on the error data of the Wernicke's aphasics did not yield significant main effects (all $Fs<1$). However, the Target Type by

Congruency interaction turned out to be significant in the subject analysis ($F(2,4)=14.00$, $MSe=.08$, $p<.05$), but not in the item analysis ($p=.26$). Planned comparisons showed only a marginally significant difference for the subordinate targets between the number of errors in the concordant and the discordant context ($F(1,2)=16.00$, $p=.06$). More errors were made in the discordant context. This, then, might explain the curious trend seen in the latency data of the subordinate targets, where latencies for the discordant context were shorter than those for the concordant context. The error data suggest that this is due to a trade-off between speed and accuracy.

Discussion

The pattern of performance for the neurologically unimpaired control subjects closely matched that of the younger subjects in Experiment 1a. Like the younger subjects, the older control subjects showed activation for the dominant meaning of ambiguous nouns, regardless of the contextual bias. Activation of the subordinate meaning only obtained in a context in which it was appropriate.

In order to interpret these results in terms of the selection/integration process, it is necessary to specify in more detail what these context effects mean, both overall and for the dominant and the subordinate meaning separately.

An overall indication for the success of contextual selection can be gained from the differential activation for targets in the concordant and the discordant context. If, in addition to facilitation relative to the unrelated baseline, targets in the concordant condition also show facilitation relative to the discordant condition, the context has been successful in selecting the appropriate meaning of an ambiguous noun, since only the contextually appropriate meaning is fully activated. The group of control subjects showed differential activation for a particular meaning of an ambiguity as a function of the contextual bias. This suggests that the selection/integration process has been completed or is close to its completion.

Normal control subjects showed activation of the dominant and the subordinate meaning in a context biasing these specific readings. In addition to activation of the biased meaning, selection requires the suppression of the unbiased meaning. To interpret the results with respect to the selection of the dominant meaning, the results for the subordinate targets in the discordant context are, therefore, especially critical. Recall that this context biases for the dominant meaning. Selection of the dominant meaning implies that in such a context the subordinate meaning has been suppressed. Suppression of the subordinate meaning can be inferred from the following results: (a) no facilitation is obtained for the subordinate targets in a context biasing the dominant reading; (b) subordinate targets show a significant difference in activation between the concordant and the discordant context. This is exactly what has been found for the control subjects. One can, therefore, conclude that elderly, neurologically unimpaired subjects have selected the dominant meaning very rapidly after an ambiguous word has been heard.

A slightly different picture emerges for the subordinate meaning. Critical in this respect are the results for the dominant targets in the discordant context, since this context biased the subordinate reading of the ambiguity. They, therefore, indicate whether suppression of the dominant meaning has taken place. Suppression of the dominant meaning is required for the selection of the subordinate meaning. This suppression can be inferred from: (a) the absence of facilitation for dominant targets in the discordant context, and (b) a significantly larger amount of activation for dominant targets in the concordant relative to the discordant context. The normal control subjects did show facilitation for the dominant targets in the discordant condition. At the same time, they did not show differential activation for the dominant targets in the concordant and discordant context. This suggests that suppression of the dominant meaning has not (yet) been completely achieved in a context biasing the subordinate reading of the ambiguity. Two reasons might be responsible for this effect. First, not enough time has passed for the selection/integration of the subordinate meaning of the ambiguity to be completed. Second, the context sentences used do not completely override the effect of meaning dominance. Which of these explanations is the more likely one, will be addressed in Experiment 2b, where a longer ISI will be used.

The group of Broca's aphasics, however, deviated from the overall picture for the younger and older control subjects. No differential overall activation emerged for targets in the concordant and the discordant context. This indicates that the selection/integration process has not (yet) selected the contextually appropriate reading of the ambiguity. The significant 66 msec facilitation for targets in the discordant context clearly demonstrates the absence of contextual selection. The results for both target types support this conclusion. Dominant and subordinate targets also did not show a significant difference in the amount of activation between the congruent and the incongruent context.

With respect to the contextual selection of the dominant meaning, the results have to be interpreted with some caution. However, the non-significant trend of facilitation for subordinate targets in a discordant context (59 msec), in combination with the absence of a significant difference with the concordant context suggests that selection of the dominant meaning has not taken place.

The subordinate meaning has not been selected either, given the 74 msec facilitation for the dominant targets in the discordant context. However, the significant facilitation for the subordinate targets in a congruent context implies that the absence of contextual selection cannot be attributed to a failure in accessing the subordinate meaning of an ambiguous word. Thus, although both the dominant and the subordinate meaning of ambiguous words are accessed, the contextual constraints have not (yet) been effective in selecting the contextually appropriate reading of the ambiguity.

Four remarks should be made with respect to these results. First, the claim by Swinney et al. (1989) that Broca's aphasics only retrieve the dominant meaning of lexical ambiguities has proven to be wrong. This claim was based on their finding that irrespective of context, Broca's aphasics showed selective facilitation for targets related to the dominant meaning of an ambiguous word. In their case, a visual target was presented at the offset of the ambiguity. With the slightly longer delay between the offset of the ambiguity and the auditory presentation of the target in this experiment, however, facilitation was also obtained for targets related to the subordinate meaning. The evidence that Broca's aphasics are perfectly capable of accessing on-line the subordinate meaning of an ambiguity in addition to its dominant meaning, by implication also falsifies the generalization that these patients show a failure of exhaustive computation in any domain of cognition (Swinney et al., 1989).

Second, with some caution these results might be taken as indirect support for an exhaustive access model, at least for the processing of ambiguous words in Broca's aphasics. Although non-significant, the data show a trend in the direction of facilitation for the subordinate targets in the incongruent context. According to an ordered access model, this should not happen. This model predicts only context-independent activation for the dominant meaning of the ambiguity. An exhaustive access model, however, predicts initial activation of both dominant and subordinate meanings, regardless of the contextual constraints. The results for the Broca's aphasics seem to be closer to the latter view.

Third, the results support the hypothesis that the temporal organization of the comprehension process has been changed in the Broca's aphasics. For the intact language processor, the temporal window for selection imposed by the present experiment was large enough to select the contextually appropriate reading of the ambiguity, at least for the dominant meaning. In contrast, the impaired language processor has not selected the appropriate reading within the same amount of time. This suggests that contextual selection is relatively delayed in Broca's aphasics.

A possible alternative interpretation is that for some reason these patients are incapable of using contextual constraints at all in selecting the appropriate reading. This would mean that increasing the interval between ambiguous word and target word should not lead to suppression of the contextually inappropriate reading. Experiment 2b will provide the answer as to which of these two possible explanations is supported by empirical evidence.

Finally, Swinney et al. (1989) also gave an alternative explanation for their results, which is in agreement with the view that the agrammatic language processor shows a change in the temporal organization of lexical processing. In this explanation they suggested that "the lexical search module in agrammatism operates on a slower-than-normal rise time, only the most frequent meaning representation being engaged within the time frame imposed by the experimental paradigm" (Swinney et al., 1989; p. 32).

In the light of the results of the present experiment this alternative explanation is less likely. In Experiment 1b, Broca's aphasics showed facilitation not only for the dominant targets, but also for the subordinate targets. One can, of course, argue that the interval of 100 msec between ambiguity and target meant that the time frame imposed by the experiment was sufficient for the subordinate meaning to reach a critical level of activation, even with a slower-than-normal rise time. However, this leaves unexplained why selection has not been occurring for the dominant meaning of the ambiguity. Swinney and his colleagues showed that the dominant meaning is already accessed when the target occurs at the offset of an ambiguous word. The results of the present experiment provide evidence that in a biasing context, the unimpaired language processor has selected the dominant meaning within a period of not much more than 100 msec after the offset of the ambiguity. The Broca's aphasics, however, had not managed to select this meaning within the same time period. This suggests that it is not (or not only) lexical access that shows a general slowing down. Contextual selection itself seems to occur at a slower-than-normal rate.

Moreover, the experiments discussed in the previous chapter did not find evidence for a general slowing down in the access of lexical items in the case of Broca's aphasics. Thus, the data seem to suggest slower-than-normal integration of lexical meanings into a sentential-semantic context. A slowing down of lexical integration leads to a delay in the selection of the contextually appropriate reading of lexical ambiguities. This idea is brought under further empirical scrutiny in Experiment 2b.

The picture is less clear for the Wernicke's aphasics. No significant effects of context were obtained, suggesting that neither meaning of the ambiguous nouns had been sufficiently activated, despite a facilitatory trend for the dominant targets in the concordant context. This result is, again, at odds with the Swinney et al. study (1989). These authors found activation of both the dominant and the subordinate meaning, irrespective of the contextual bias. It might be that activation of lexical meanings rapidly decays when integration into a higher-level representation fails. Further discussion of this possibility will be postponed until the general discussion.

Experiment 2a

In Experiment 2a a group of younger subjects is tested on the same materials as in Experiment 1a, but with a longer interval between sentence offset and target onset. The results of this Experiment should provide the standard of comparison for Experiment 2b in which aphasic patients and their neurologically intact controls are tested.

Method

Subjects
Thirty-six subjects from the MPI subject pool, mainly students, participated in this experiment. All subjects were native speakers of Dutch, and were paid for their participation. None of the subjects had participated in Experiment 1a.

Materials
The same materials were used as in Experiment 1a, with one important change. With the help of a speech waveform editing system the interval of silence (ISI) between sentence offsets and target onsets was increased to 750 msec. Four new test tapes were constructed. One tape contained the practice items, the other three tapes contained the three blocks of test items. The output from the computer was low-pass filtered with a cutoff frequency of 10 kHz. Apparatus and procedure were the same as in Experiment 1a.

Results

Errors on word targets and missing values were replaced in the same way as in Experiment 1a. Analyses on latency and error data were done according to the procedures specified for Experiment 1a.

Latency analyses

Table 7 presents a summary of the latency data for the different sentence-target conditions.

TABLE 7

Means (both across and by Target Type) of the median auditory lexical decision times as a function of Context Condition (ISI=750 msec).

ISI=750 msec	Overall		Dominant		Subordinate	
Context Condition	RT	d	RT	d	RT	d
	Students (N=36)					
Concordant	610	66	591	57	628	75
Discordant	656	20	624	24	688	15
Unrelated	676		648		703	

Differences (d) are measured relative to the unrelated baseline.

An overall ANOVA on the medians per condition revealed a significant main effect of Target Type ($F(1,35)=128.70$, $MSe=1133$, $p<.0001$). Latencies were on average 52 msec longer for the subordinate targets. A significant effect was also obtained for Congruency ($F(2,70)=49.81$, $MSe=1660$, $p<.0001$). Compared to both the discordant and the unrelated condition, lexical decision latencies were shortest in the concordant context. The main effect of Congruency was qualified by a significant Target Type by Congruency interaction ($F(2,70)=3.88$, $MSe=853$, $p<.05$), which, however, did not approach significance in the item analysis ($p=.39$). Separate ANOVAs for both levels of Target Type yielded significant effects of Congruency for dominant targets ($F(2,70)=26.50$, $MSe=1110$, $p<.0001$), as well as for subordinate targets ($F(2,70)=40.32$, $MSe=1403$, $p<.0001$).

Planned comparisons, testing the differences between the three context conditions for the dominant targets, revealed significant facilitation for the concordant context relative to the unrelated context ($F(1,35)=38.38$, $p<.0001$), and relative to the discordant context ($F(1,35)=18.40$, $p=.0001$). Moreover, the latency difference between targets in the discordant and the unrelated context was also significant ($F(1,35)=13.80$, $p<.001$).

For the subordinate targets, planned comparisons yielded significantly shorter latencies in the concordant context relative to both the unrelated baseline ($F(1,35)=61.93$, $p<.0001$) and the discordant context

($F(1,35)=49.37$, $p<.0001$). The 15 msec difference between the discordant and the unrelated condition was only marginally significant ($F(1,35)=3.33$, $p=.08$)

In summary, both dominant and subordinate targets showed facilitation in the concordant context relative to the other two context conditions. Some facilitation was also obtained in the discordant context. The amount of facilitation in this context was, however, significantly reduced in comparison to the facilitation in the concordant context.

Error analyses

A summary of the error data is presented in Table 8. Errors were made on 3.5% of the critical word target trials. The pattern of results for the error data was in general agreement with that of the latency data. Least errors were made in the concordant context. Most errors were made in the unrelated context.

TABLE 8

Mean percentage of errors (and total number of errors), across and by Target Type, as a function of Context Condition (ISI=750 msec).

ISI=750 msec	Overall	Dominant	Subordinate
Context Condition			
	Students (N=36)		
Concordant	1.9 (16)	1.9 (8)	1.9 (8)
Discordant	3.4 (29)	1.9 (8)	4.9 (21)
Unrelated	5.2 (45)	4.4 (19)	6.0 (26)

An overall ANOVA obtained a significant main effect of Congruency ($F(2,70)=7.20$, $MSe=0.41$, $p<.005$). The effect of Target Type was only marginally significant ($F(1,35)=4.01$, $MSe=0.46$, $p=.053$). Most errors were made to subordinate target items. The Target Type by Congruency interaction did not approach significance ($F(2,70)=1.48$, $MSe=0.40$, $p=.23$).

Planned comparisons on the error scores of the dominant targets showed that significantly more errors were made in the unrelated context compared to the concordant context ($F(1,35)=4.26$, $p<.05$), and compared to the discordant context ($F(1,35)=5.99$, $p<.05$). No significant difference was obtained between the error scores in the concordant and the discordant condition ($F<1$).

For the subordinate targets, planned comparisons yielded significant differences between the concordant and the unrelated condition ($F(1,35)=9.55$, $p<.005$), and between the concordant and the discordant condition ($F(1,35)=4.53$, $p<.05$). Less errors were made in the concordant context than in both the unrelated context and the discordant context. The error scores for the latter two conditions did not differ significantly from each other ($F<1$).

In conclusion, the pattern of results for the error data in no way contradicts that of the latency data. A speed-accuracy trade-off was not obtained.

All subjects were aware that some targets were repeated, and some subjects confirmed that they had been aware of the presence of ambiguous words. To exclude the possibility of confounding effects due to the repetition of target words and ambiguous nouns, analyses were also performed on the first-block data only. As in Experiment 1a, the results of these analyses closely correspond to the overall analyses.

A first-block ANOVA on the latency data yielded significant main effects of Target Type ($F(1,35)=30.03$, $MSe=4567$, $p<.0001$) and Congruency ($F(2,70)=23.18$, $MSe=4784$, $p<.0001$). The Target Type by Congruency interaction was not significant ($F(2,70)=1.51$, $MSe=5477$, $p=.22$). Planned comparisons yielded the same pattern of differences as in the overall analyses.

The dominant targets showed significant facilitation in the concordant context relative to the unrelated context ($F(1,35)=13.30$, $p<.001$), and relative to the discordant context ($F(1,35)=5.90$, $p<.05$). The 28 msec difference between the discordant and the unrelated context was only marginally significant ($F(1,35)=3.30$, $p=.08$).

Targets related to the subordinate meaning of the ambiguity had shorter latencies in the concordant context than in both the unrelated context ($F(1,35)=22.13$, $p<.0001$), and the discordant context ($F(1,35)=19.81$, $p=.0001$). The 8 msec difference between the discordant and the unrelated condition did not approach significance ($F<1$).

A first-block ANOVA on the error data showed a significant effect of Congruency ($F(2,70)=5.26$, $MSe=0.24$, $p<.01$). The effect of Target Type was marginally significant ($F(1,35)=3.71$, $MSe=0.21$, $p=.06$). No significant Target Type by Congruency interaction emerged ($F(2,70)=1.61$, $MSe=0.21$, $p=.21$). Planned comparison yielded the same pattern of differences as in the overall analyses.

Planned comparisons on the error data of the dominant targets revealed that the number of errors in the unrelated context was significantly larger than in the concordant ($F(1,35)=6.18$, $p<.05$) or the discordant context ($F(1,35)=5.09$, $p<.05$). The number of errors in the concordant and the discordant context did not differ significantly from each other ($F<1$).

For the subordinate targets, planned comparisons showed that less errors were made in the concordant context compared to both the discordant ($F(1,35)=5.65$, $p<.05$) and the unrelated context ($F(1,35)=5.64$, $p<.05$). The error scores for the latter two contexts did not differ significantly from each other ($F<1$).

As in Experiment 1a, the pattern of results for the first-block analyses was similar to the pattern obtained in the overall analyses. The repetition of ambiguous words and targets did not seem to have a specific, confounding effect on the overall pattern of results.

Discussion

The pattern of results in Experiment 2a closely corresponds to that of Experiment 1a. Again, contextual selection has taken place for both dominant and subordinate meanings of the ambiguity, as was indicated by the facilitation of the targets in the concordant context relative to the discordant context. With the time interval used in this experiment, one can assume that contextual selection has been completed (cf. Seidenberg et al., 1982). Nevertheless, partial activation of the dominant meaning was still present in the context that biased the subordinate meaning. This indicates that the context did not fully override the effect of dominance. Provided that the contextual constraints are not very strong, activation of the dominant meaning of ambiguous words with a large difference between the frequencies of their alternative readings is apparently not completely suppressed.

Experiment 2b

Experiment 2b tests neurologically unimpaired, elderly subjects and the aphasic patients with the same materials as in Experiment 1b, but with a longer interval between sentence offsets and target onsets. If selection of the contextually appropriate reading of lexical ambiguities is slower-than-normal in Broca's aphasics, then with the extended time frame imposed by Experiment 2b these patients are expected to show the normal selective facilitation for targets related to the contextually appropriate reading. If, in contrast, these patients fail to integrate the lexical meanings into the higher-level message representation, no evidence of contextual selection will be obtained. In this case, the results of Experiment 2b should be the same as those in Experiment 1b.

Method

The same group of twelve aphasic patients as in Experiment 1b, and another group of twelve normal controls participated in Experiment 2b. The normal control subjects were matched in age and education with the aphasic patients. Their mean age was 53 years (range: 48-61). Patients were tested in Experiment 1b and 2b with an interval of at least three weeks.

Materials and apparatus were the same as in Experiment 2a. The procedure was identical to the one in Experiment 1b.

Results

In analyzing the results the same procedures were used as in Experiment 1b. The results for the three subject groups were analysed separately.

Latency analyses
A summary of the results for the normal control subjects, the Broca's aphasics and the Wernicke's aphasics is presented in Table 9. For the normal control subjects an overall ANOVA showed significant effects of Target Type ($F(1,11)=97.56$, $MSe=636$, $p<.0001$) and Congruency ($F(2,22)=13.60$, $MSe=1098$, $p=.0001$). Latencies to subordinate targets were on average 59 msec longer than those to dominant targets. The Target Type by Congruency interaction was only marginally significant ($F(2,22)=2.69$, $MSe=839$, $p=.09$). Planned comparisons yielded significant facilitation for targets in the concordant context relative to both the unrelated context ($F(1,11)=17.60$, $p<.0005$) and the discordant context ($F(1,11)=11.23$, $p<.01$). The 11 msec difference between the latter two conditions was only marginally significant ($F(1,11)=4.68$, $p=.053$).

Planned comparisons revealed that for the dominant targets only the difference between the the concordant and the unrelated context was marginally significant ($F(1,11)=3.16$, $p=.10$). Neither the 12 msec difference between the discordant and the unrelated context ($F(1,11)=1.00$, $p=.34$), nor the 19 msec difference between the concordant and the discordant context approached significance ($F(1,11)=2.76$, $p=.13$).

The planned comparisons for the subordinate targets showed significant facilitation for targets in the concordant context relative to the unrelated baseline condition ($F(1,11)=46.39$, $p<.0001$), and relative to the discordant

TABLE 9

Means (both across and by Target Type) of the median auditory lexical decision times as a function of Context Condition (ISI=750 msec).

ISI=750 msec	Overall		Dominant		Subordinate	
Context Condition	RT	d	RT	d	RT	d
	Normal Controls (N=12)					
Concordant	710	47	692	31	728	64
Discordant	746	11	711	12	782	10
Unrelated	757		723		792	
	Broca's Aphasics (N=9)					
Concordant	858	65	853	52	863	78
Discordant	894	29	867	38	921	20
Unrelated	923		905		941	
	Wernicke's Aphasics (N=3)					
Concordant	1024	55	958	58	1090	52
Discordant	1040	39	1000	16	1080	62
Unrelated	1079		1016		1142	

Differences (d) are measured relative to the unrelated baseline.

context ($F(1,11)=13.98$, $p<.005$). Latencies in the latter two context conditions did not differ significantly from each other ($F(1,11)=1.15$, $p=.31$).

In summary, the normal control subjects only showed facilitation for dominant and subordinate targets in the concordant context biasing the target-related reading of the ambiguity.

An overall ANOVA on the latency data of the Broca's aphasics yielded a significant effect of Congruency ($F(2,16)=5.16$, $MSe=3422$, $p<.05$). The effect of Target Type was not significant ($F(1,8)=3.12$, $p=.12$). The Target Type by Congruency interaction did not approach significance either ($F(2,16)=1.33$, $p=.29$). Planned comparisons testing the overall differences between the three context conditions, showed that the lexical decision latencies were significantly shorter in the concordant context compared to both the unrelated baseline condition ($F(1,8)=7.71$, $p<.05$) and the discordant context ($F(1,8)=6.78$, $p<.05$). The difference between the discordant context and the unrelated baseline condition failed to reach significance ($F(1,8)=2.12$, $p=.18$).

Planned comparisons revealed that dominant targets were facilitated in the concordant condition relative to the unrelated baseline ($F(1,8)=5.64$, $p<.05$). The difference between the discordant condition and the unrelated condition failed to reach significance ($F(1,8)=2.73$, $p=.14$), as did the difference between the concordant and the discordant condition ($F<1$).

The subordinate targets were shown to be facilitated relative to the baseline in the concordant condition ($F(1,11)=5.81$, $p<.05$), but not in the discordant condition ($F<1$). Moreover, facilitation was obtained for the subordinate targets in the concordant context relative to the discordant context ($F(1,8)=9.89$, $p<.05$).

In summary, the Broca's aphasics showed selective facilitation for targets related to the contextually biased reading of ambiguous words. Moreover, differential activation was obtained for subordinate targets in a concordant and a discordant context.

An ANOVA on the latency data of the Wernicke's aphasics only revealed a significant effect of Target Type ($F(1,2)=39.44$, $MSe=1447$, $p<.05$). Latencies were on average 113 msec longer for the set of subordinate target words. Neither the effect of Congruency ($F<1$), nor the Target Type by Congruency interaction ($F(2,4)=2.23$, $MSe=565$, $p=.22$) approached significance. The planned comparisons did not yield any significant difference. Despite a slight tendency for facilitation when targets were related to the ambiguous nouns, no significant context effects were obtained, neither for the dominant nor for the subordinate targets.

Error analyses

Table 10 summarizes the error data for the normal control subjects and both patient groups. The normal control subjects made errors on 2.1% of the critical word target trials. For this group of subjects no significant main effects or interactions were obtained in an overall ANOVA on the error data. None of the planned comparisons yielded a significant difference between the numbers of errors in the three context conditions.

The Broca's aphasics made errors on 4.0% of the critical word target trials. The ANOVA on their error scores did not yield a significant Congruency effect ($F<1$). The effect of Target Type was marginally significant in the subject analysis ($F(1,8)=4.00$, $MSe=0.17$, $p=.08$), but not in the item analysis ($p=.22$). More errors were made on subordinate than on dominant target trials. No significant Target Type by Congruency

TABLE 10

Mean percentage of errors (and total number of errors), across and by Target Type, as a function of Context Condition (ISI=750 msec).

ISI=750 msec	Overall	Dominant	Subordinate
Context Condition			
	Normal Controls (N=12)		
Concordant	1.4 (4)	1.4 (2)	1.4 (2)
Discordant	2.4 (7)	0.7 (1)	4.2 (6)
Unrelated	2.4 (7)	2.8 (4)	2.1 (3)
	Broca's Aphasics (N=9)		
Concordant	2.8 (6)	3.7 (4)	1.9 (2)
Discordant	5.1 (11)	2.8 (3)	7.4 (8)
Unrelated	4.2 (9)	2.8 (3)	5.6 (6)
	Wernicke's Aphasics (N=3)		
Concordant	5.6 (4)	2.8 (1)	8.3 (3)
Discordant	8.3 (6)	5.6 (2)	11.1 (4)
Unrelated	9.7 (7)	8.3 (3)	11.1 (4)

Differences (d) are measured relative to the unrelated baseline.

interaction was obtained ($F(2,16)=1.00$, $p=.39$). Planned comparisons only obtained a significant difference between the concordant and the discordant context for the subordinate targets ($F(1,8)=5.33$, $p<.05$). This effect is in the same direction as the latency difference between these conditions.

The Wernicke's aphasics had an overall error score of 7.9%. An ANOVA on the error data of these patients did not yield any significant effect. The planned comparisons also failed to find significant differences.

In conclusion, the results of the error analyses for the neurologically intact control subjects and both patient groups are in no way incompatible with the results of the analyses on their latency data.

Discussion

Although statistically weaker, the results of the neurologically intact control subjects were in most respects very similar to those of the younger subjects in Experiment 2a. Overall, facilitation again emerged in the concordant context relative to both other context conditions. This can be taken as a general indication that context has been successful in selecting the appropriate reading of the ambiguity.

Selection of the dominant meaning is indicated by the absence of a facilitatory effect for the subordinate targets in the context biasing the dominant meaning. Although only marginally significant, facilitation of dominant targets in a congruent context indicated the activation of the dominant meaning. Together these results provide evidence for the activation of the dominant and the suppression of the subordinate meaning in a context that biases the dominant reading of an ambiguous word.

The same picture is seen for the subordinate meaning. Targets related to this meaning are facilitated in a context with a bias in the direction of the subordinate reading of the ambiguity, while no facilitation is obtained for dominant targets in such a context.

Thus, the results indicate that within a time frame of about 750 msec following the offset of the ambiguity, contextual selection had been fully completed for both dominant and subordinate meanings of ambiguous nouns.

The pattern of results for the Broca's aphasics closely matched that of the normal controls. The overall results indicate differential activation in the concordant and the discordant context. This implies that context has been successful in selecting the appropriate reading of the ambiguity. The pattern of results for both the dominant and the subordinate meaning also closely corresponded to that of the elderly control subjects.

The facilitation of dominant targets in the concordant context together with the absence of facilitation for the subordinate targets in a discordant context, indicated that selection of dominant meanings had been completed.

The data also provide evidence for the selection of the subordinate meaning. Contexts biasing this meaning led to facilitation of subordinate targets, but not to facilitation of dominant targets. The remaining non-significant difference of 38 msec relative to the unrelated baseline, and the absence of a reliable difference with the concordant context suggest that partial activation of the dominant meaning might still be present. Just as for the younger subjects, this can be attributed to an effect of meaning dominance which could not be completely overridden by the context information.

Most important for the interpretation of the results is a comparison between the performance of the Broca's aphasics in both experiments. No selection of the contextually appropriate reading had occurred, when probing 100 msec after the offset of the ambiguous nouns. However, within an interval of 750 msec, contextual selection had been completed. This result supports the idea that Broca's aphasics can use contextual constraints for selecting the appropriate reading of ambiguous words, but show a relative delay in the moment at which the selection/integration process finds its completion.

For the Wernicke's aphasics again no evidence was found for the contextual selection of the appropriate reading. Significant facilitation for related targets was not obtained, despite a trend in the data showing shorter latencies when the target followed the related sentence-final ambiguity, than when the target followed the unrelated control word. Given the limited number of Wernicke's aphasics that was tested, the power of the test might have been too reduced to find a significant effect of the suggested lexical access of both meanings.

General discussion

An important indication for the effect of context in selecting one specific meaning of ambiguous nouns, was obtained from the difference in the amount of activation for this meaning between a congruent and an incongruent context. Figure 1 shows this difference for the four subject groups, both for the short and the long interval between lexical ambiguities and targets.

As can be seen, the Broca's aphasics differ from the three other subject groups, in that the differential activation has increased substantially at the long interval, relative to the short interval. This illustrates the finding that in these patients lexical selection is delayed, relative to the moment at which it has been completed in the intact language processing system. The individual patient data support this overall group result. At the ISI of 100 msec four out of nine patients had shorter latencies in the concordant context relative to the discordant context, while this increased to seven out of nine at the long ISI. Thus, the conclusion seems warranted that the time course of meaning selection is slowed down in Broca's aphasics.

The selection of the contextually appropriate meaning is dependent upon the temporal coordination of lexical access and the integration of activated lexical meaning(s) into a higher-level message representation. A slowing down in either of these processes can result in a slower-than-normal selection of the contextually appropriate meaning.

If lexical access, i.e., the retrieval of lexical meanings on the basis of the sensory input, is slower-than-normal, these lexical meanings will be available later than normal for integration with the context. This is one of the accounts given by Swinney et al. (1989). Although a slower-than-normal rise time for the activation of lexical-semantic information cannot be excluded given the time frames imposed by the experiments, it is not sufficient to explain the delay in contextual selection. Swinney and his colleagues found that despite a possible slowing down of lexical access, at word offset activation was shown for the dominant meaning. Experiment 1b provided evidence for the claim that in the case of neurologically unimpaired subjects, contextual constraints are used for selecting the dominant meaning within about 100 msec. However, the Broca's aphasics showed activation but not selection of the dominant meaning within the same time frame. Together, these results suggest that, if at all, lexical access is not the only process that is slowed down in its operation. The suppression of the contextually inappropriate meaning must be slower-than-normal too.

Not very much is known about the nature of the suppression mechanism. One reason here is that our knowledge about the integration process is not yet very well developed. Despite the lack of a detailed specification for the suppression mechanism, some fairly general proposals have been made. One view is based on the dichotomy between automatic and controlled processing (Neely, 1977; Posner & Snyder, 1975; Shiffrin & Schneider, 1977). Along the lines of this framework, it is proposed that after the initial automatic activation of both meanings, attention is allocated to the contextually appropriate meaning, with the inhibition of the inappropriate meaning as its concomitant result (cf. Simpson, 1984). The speed of contextual selection and the lack of awareness by the subjects of the multiple-meaning character of ambiguous words when processed in context, are arguments against a suppression mechanism under full attentional control. Some authors, therefore, argue that suppression of the inappropriate meaning is better described as a veiled control process (Tanenhaus et al., 1979).

In contrast to this two-stage account of contextual selection, recent connectionist models (e.g., Kawamoto, 1988) do not regard selection of the appropriate meaning as a discrete process. In this type of model, initially both meanings of the ambiguous word are activated on the basis of the sensory input. With time, context starts to contribute to the activation of one of the readings. This reading eventually becomes fully activated, winning the competition with the alternative reading(s).

In both of the above accounts of ambiguity resolution, selection is made dependent upon the success of integrating the contextual information and one particular meaning of the ambiguity into a message representation.

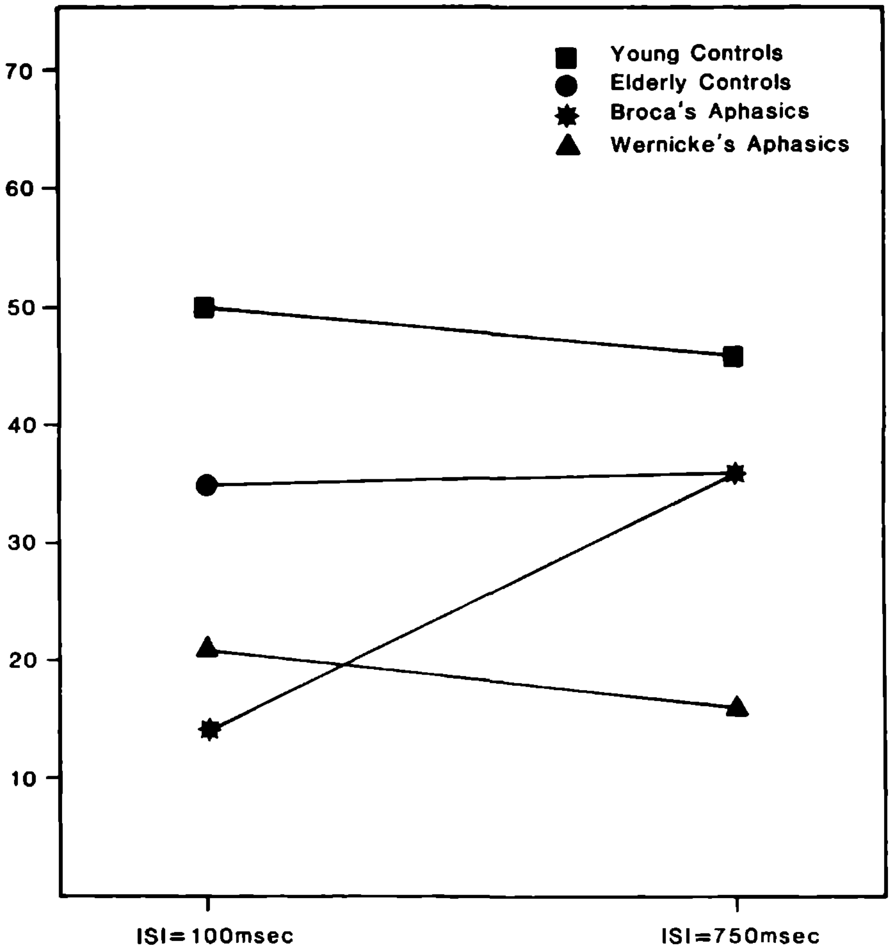

Figure 1: Overall facilitation of targets in the concordant context relative to the discordant context, for the young control subjects, the elderly control subjects, the Broca's aphasics, and the Wernicke's aphasics.

Selection is thus seen as the by-product of lexical integration, either leading to active inhibition or to passive decay of the alternative readings.

The Broca's aphasics' delay in meaning selection, therefore, is most probably due to their inability to integrate lexical meanings into a message representation, at a normal rate. Contextual constraints can be used by these patients, but it seems as if context has to catch up with the lexical meanings that are made available very rapidly by the lexical processor. This change in the 'kinetic melody' (Von Monakow, 1914) of lexical access and lexical integration might lead to specific problems in the on-line exploitation of those types of information for which a tight temporal coordination seems to be critical. Syntactic information is the prime example. Forming a constituent structure and using its syntactic constraints during the integration of lexical information, relies more heavily on the correct temporal structuring of the incoming information than the integration of separate lexical meanings into a final interpretation of the utterance. In the latter case, the patients' world knowledge can be used to bind the lexical meanings together, even when they are delivered in an incorrect temporal order. This, then, might explain why comprehension deficits in Broca's aphasics are most clearly visible when the message representation critically depends on syntactic information (e.g., in semantically reversible sentences). The next chapter will present experimental data explicitly addressing the time course with which Broca's aphasics use syntactic constraints to resolve lexical ambiguity.

The results for the Wernicke's aphasics are less clear-cut. Despite the overall non-significant trend of some facilitation for the targets preceded by a related ambiguity, a reliable pattern of contextual selection did not arise in either of the experiments. Recent studies which also used a lexical decision task have obtained clear semantic priming effects for Wernicke's aphasics (see previous chapter). Moreover, Swinney et al. (1989) found that in these patients the normal pattern obtained of multiple access of both the dominant and the subordinate meaning. The combined results of these studies suggest that the often severe comprehension deficits of Wernicke's aphasics cannot be attributed to a failure in the automatic retrieval of lexical meanings. It seems more likely that their comprehension problems arise at a post-lexical level, when the accessed lexical meanings have to be integrated into a higher-level message representation. For some reason, this integration process fails, resulting in a failure to construct an overall interpretation of the utterance. This, for instance, might explain why the Wernicke's aphasics were so much worse than the Broca's aphasics in answering the questions that were asked after a subset of the sentences (e.g., "What did he buy ?", "Where did he go to?"). Answering these questions requires that some kind of representation spanning the whole utterance is constructed. It is suggested that despite their more or less normal intra-lexical processing, Wernicke's aphasics suffer from an often severe comprehension deficit because of their inability to integrate the activated lexical information into a message representation.

5

TRACKING THE TIME COURSE OF MEANING SELECTION IN APHASIA: SYNTACTIC CONTEXT EFFECTS

According to the standard conception of the classical view on Broca's aphasia (Isserlin, 1922; Pick, 1913), the syntactic disorders seen in patients with this syndrome are believed to be restricted to language production (e.g., Goodglass, 1973; but for a more accurate view on the history of especially the German tradition in aphasiology, see De Bleser, 1987). Later experimental research, however, found that very often Broca patients were also syntactically impaired in their language comprehension (Caramazza & Zurif, 1976; Heilman & Scholes, 1976). This led to the view that underlying Broca's aphasia is a central syntactic deficit which is characterized by of a loss of syntactic algorithms. Knowledge structures (including procedural knowledge) required for the construction of a syntactic representation are assumed to be no longer available for processing (see Berndt & Caramazza, 1980). This conception has recently been challenged, mainly by studies reporting a relatively high level of performance for agrammatic patients in judging the grammaticality of auditorily presented sentences (Linebarger, Schwartz, & Saffran, 1983a; Lukatela, Crain, & Shankweiler, 1988; Shankweiler, Crain, Gorrell, & Tuller, 1989). In the Linebarger et al. study, the same subjects that showed a good performance in the grammaticality judgement task, were found to be much worse on sentence-picture matching and acting-out tasks. These findings are difficult to account for by a syntactic loss hypothesis. The loss of syntactic knowledge would not allow for a relatively good performance on certain syntactic tasks, and at the same time a relatively bad performance on other tasks that require the processing of similar syntactic information. Neither can the syntactic loss hypothesis easily account for differences in the degree of severity between patients with the same aphasic syndrome. An example in case is the reported variability in the number of errors different agrammatic patients made in a test on the comprehension of word order. Despite this variability, all patients showed a qualitatively similar error pattern (Kolk & van Grunsven, 1985).

In view of the questions raised by the within-patient variability in performance on different tasks tapping aspects of syntactic processing (e.g., Linebarger et al., 1983a), and by the variability in performance between patients tested with the same task (e.g., Kolk & van Grunsven, 1985), in recent years we have seen a pendulum swing from the conception of Broca's aphasia as a (partial) loss of syntactic competence to the view that agrammatism might rather be the result of a processing deficit (e.g., Baum, 1988, 1989; Friederici & Kilborn, 1989; Kolk & van Grunsven, 1985; Lukatela et al., 1988; Menn & Obler, 1990; Shankweiler et al., 1989; Tyler & Cobb, 1987). That is, agrammatic aphasics have not lost part of their syntactic knowledge, but are impaired in exploiting this knowledge in real time during the construction of a syntactic representation.

To further delineate the nature of this computational deficit, one has to rely on on-line tasks in which the dependent measure is tightly time-locked to aspects of the ongoing language processing events. In this way, one can try to determine at what level of processing computational deficits emerge. Moreover, by using on-line tasks the degrees of freedom for compensatory strategies can be reduced. In general, strategies require time to become operative (cf. Posner & Snyder, 1975). Off-line tasks, giving patients all the time in the world to solve the problem imposed by the experiment, encourage the use of cognitive strategies to compensate for language processing deficits. In contrast, on-line tasks reduce the chance that the agrammatic patient uses "processing routes other than those by which structural information is normally made available at the appropriate time for interpretation." (Zurif & Grodzinsky, 1983, p. 208).

Regarding comprehension deficits in agrammatic patients, there is mounting evidence from on-line studies that the impairment in developing a fully specified syntactic representation of an utterance might, at least in part, be due to a deficit in the on-line exploitation of syntactic information associated with closed class morphemes.

A recent example is a word monitoring study by Tyler and Cobb (1987). These authors found no difference for their agrammatic patient D.E. between monitoring latencies for targets following contextually appropriate or contextually inappropriate inflections, while normal control subjects showed an on-line sensitivity to this kind of syntactic violation. They presented this as evidence for the claim that their agrammatic patient cannot access the syntactic properties of inflectional suffixes (see also Tyler, Behrens, Cobb, & Marslen-Wilson, 1990).

Bradley, Garrett, and Zurif (1980) have made a comparable claim for free standing closed class morphemes on the basis of a study measuring lexical decision times to isolated open and closed class words. Bradley et al. argue that for parsing operations, a special route to the closed class items in the mental lexicon is available, in addition to the general route to all the items in the mental lexicon. Access via this special route is claimed to be no longer possible in Broca's aphasia. As a consequence, these patients have lost the ability to employ the closed class vocabulary in computing a rapid structural assignment of the input. Despite the lack of success in replicating the original results (Gordon & Caramazza, 1982; Kolk & Blomert, 1985; Segui, Mehler, Frauenfelder, & Morton, 1982), other on-line studies in which closed class words were presented in a sentence context also obtained deviant patterns of performance for only closed class words (Friederici, 1983; Swinney, Zurif, & Cutler, 1980).

These results have led to the view that one of the computational deficits in agrammatism concerns the access of syntactic information associated with closed class morphemes, be they bound or free standing. One possibility is that the access to syntactic information is no longer possible (e.g., Tyler & Cobb, 1987). An alternative is that there is a temporal mismatch between the availability of lexical-semantic and structural information (Friederici, 1988b). According to this view, the activation of syntactic information is differentially affected, in that this type of information shows a decrease in the activation rate relative to the activation rate of semantic information associated with lexical items. Closed class elements play an important role in the fast computation of structural assignments. A delay in the activation of their syntactic aspects would, therefore, hamper the correct structural assignment of lexical elements.

Other on-line studies (Baum, 1989; Hagoort, 1989a; Tyler, 1985, 1989) have shown that Broca's aphasics seem to be sensitive to local, but not to long-distance syntactic dependencies. Hagoort (1989a) did a word monitoring study that focused on the question of how long syntactic information associated with certain classes of inflectional morphemes was available to the syntactic processor in agrammatic patients. In his experiments, a subset of the materials violated the number agreement between the subject noun phrase and the finite verb. In addition to this manipulation of the agreement relation, the distance between the subject-NP and the critical finite verb was varied. In the short-distance version, the subject-NP and the finite verb belonged to the same clause; in the long-distance version these elements were part of different clauses. Subjects had to monitor for a word that immediately followed the critical finite verb. When the number agreement was violated, normal subjects showed longer latencies in both the short-distance and the long-distance version of the sentences. However, for the agrammatic aphasics an effect of this violation was only seen in the short-distance version.

Baum (1989) obtained very similar results in a word monitoring study with a number of other syntactic violations (e.g., in verb-argument and filler-gap relations). Her findings, however, suggest that not so much distance, but rather structural differences might be responsible for a differential effect in the processing of local and long-distance dependencies.

Tyler (1985, 1989) in her studies with D.E. did not obtain the normal serial word order effect in monitoring studies that presented semantically incoherent but syntactically structured sentences to this agrammatic patient. In normal subjects, a decrease in monitoring latencies to targets further downstream in semantically anomalous sentences is a standard effect (Marslen-Wilson & Tyler, 1980). This word position effect is interpreted as indicating the on-line construction of a global structural representation spanning an entire clause or utterance (Marslen-Wilson & Tyler, 1980; but see Tyler & Warren, 1987, for a different view). Although D.E. did not show this serial position effect, he seemed to be sensitive to local syntactic violations of word order constraints at the level of the phonological phrase, provided that the prose was semantically anomalous.[1] In normal prose, D.E. did not show an effect of local syntactic violations. This surprising difference in the consequences of local syntactic violations between anomalous and normal prose is attributed to D.E.'s reliance on pragmatic information, which allows him to compensate for the syntactic violations in normal prose during the construction of a message representation of the utterance (Tyler, 1989). Together, these results are taken as evidence for D.E.'s ability to build local structures, and his inability to combine local structures into global constituent hierarchies (Tyler, 1985, 1987, 1989).[2]

The monitoring studies discussed above, however, confounded to a greater (Hagoort, 1989a) or lesser (Baum, 1989) extent physical distance (in terms of the number of intervening words) and syntactic structure. Thus, it is not clear whether the obtained effects were due to a faster-than-normal decay of syntactic information or whether they have to be attributed to an inability to process more complex syntactic structures. It is even likely that both explanations are interdependent, in that faster decay of syntactic information from a parsing buffer has more devastating consequences for complex structural representations than for relatively simple ones.

This study explicitly addresses only the issue of temporal aspects of syntactic processing in Broca's aphasia (in contrast to issues of structural complexity). The previous chapter focused on the selection of lexical meanings on the basis of sentential-semantic context information. Here, I will focus on the time course of meaning selection in a syntactic context.

In this kind of context, selection of the contextually appropriate meaning presupposes the generation of some minimal structure (say, at the level of a syntactic phrase), and the processing of morphosyntactic information encoded in the word forms. By testing the selection of lexical meanings in a syntactic context, the question can be answered whether in Broca's aphasics syntactic information is available at the appropriate moments in time to allow the parser to operate with optimal efficiency.

In addition to its focus on the temporal aspects of syntactic processing, this study differs in another important respect from previous on-line studies on aspects of agrammatism. In all the relevant on-line studies to date, the syntactic comprehension deficits in Broca's aphasics have been tapped into by comparing latencies on sentences with and sentences without a grammatical violation (Baum, 1988, 1989; Hagoort, 1989a; Friederici & Kilborn, 1989; Shankweiler et al., 1989; Tyler, 1985, 1989; Tyler & Cobb, 1987). The disadvantage of directly measuring the consequences of syntactic violations, is that one cannot be sure that the absence of an effect is due to a syntactic deficit of some sort, instead of reflecting the employment of automatic compensatory processing operations which mask the sensitivity to structural information. Tyler (1989) suggests that her D.E. does not show an effect of local syntactic violations in normal prose, because here he fully relies on pragmatic information to construct a message representation. Shankweiler et al. (1989) suggest that agrammatic patients might automatically correct syntactic violations, which results in an apparent lack of sensitivity to syntactic aspects of the utterance. This possibility receives support from a case-study by Haiganoosh Whitaker (1976). She reported a profoundly aphasic patient with severe comprehension problems, who in a repetition task automatically corrected syntactic violations, but not semantic anomalies. In all, these considerations suggest that an experimental situation that requires syntactic information to be processed in order to generate a correct message representation, might provide a better indication of possible deficits in the processing of syntactic information.

However, none of the on-line studies concerning syntactic deficits measured the consequences of a possible deficit in the computation of a syntactic representation for the construction of a semantic interpretation of the utterance. Although it has been stated that "a patient who fails to construct a normal syntactic representation cannot be building a normal semantic representation either" (Tyler, 1989, p. 333), the consequences of the syntactic failure for the development of a semantic representation have not been directly investigated. Nevertheless, this is a central issue in understanding the comprehension deficits in Broca's aphasia.

To investigate syntactic processing via its consequences for the construction of a semantic representation, I used noun-verb ambiguities for which the different meanings are associated with a different form class.[3] Provided that the context does not contain a semantic bias in the direction of either reading, syntactic context information has to be used to select the contextually appropriate reading of the ambiguity.

Relatively few studies have investigated the resolution of lexical ambiguity in a syntactic context (Oden & Spira, 1983; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus & Donnenwerth-Nolan, 1984; Tanenhaus, Leiman, & Seidenberg, 1979). These studies confirm the general picture obtained for noun-noun ambiguities (see previous chapter). That is, initially both the noun and the verb reading of a noun-verb ambiguity are accessed, regardless of the contextual bias (Seidenberg et al., 1982; Tanenhaus et al., 1979). Within about 200 msec after the offset of the ambiguous word, the syntactic context has succeeded in selecting the contextually appropriate reading (Seidenberg et al., 1982; Tanenhaus et al., 1979).

The previous chapter provided evidence that Broca's aphasics are relatively delayed in selecting the contextually appropriate meaning of ambiguous words on the basis of sentential-semantic context information. This chapter investigates whether selection occurs at all in Broca's aphasics if it is dependent upon syntactic context information, and, if so, whether contextual selection occurs at a normal rate. To answer these questions, the resolution of lexical ambiguity for ambiguous words with a noun and a verb reading is investigated with a short and a long ISI between ambiguous words and targets. The sentence context indirectly biases one of the meanings via a syntactic bias towards either of the associated form classes.

If Broca's aphasics cannot exploit morphosyntactic information at all in building minimal local structures, no selection will occur at either short or long ISIs. The more likely result, however, is that ultimately these patients can exploit syntactic information, but are delayed in the on-line use of syntactic information associated with closed class morphemes. In this case, the selection process will be completed at the long ISI, but multiple activation will still be seen at the short ISI (under the assumption that the control subjects have completed contextual selection within the time frame imposed by this short ISI).

The ISIs (100 msec and 750 msec) and the presentation paradigm were the same as in the study on the resolution of lexical ambiguity for words with two noun readings (chapter 4). The argumentation for the choice of these particular ISIs was given in the previous chapter.

With respect to the subject groups, the following procedure is chosen. First, a group of younger normal control subjects is tested. Their results allow a comparison with previous studies on the processing of noun-verb ambiguities in a syntactic context. The next step is to test the Broca's aphasics and a group of neurologically unimpaired normal controls who are matched in age and education with these patients. The results for the normal controls should indicate whether young and elderly subjects obtain similar patterns of performance. Next, the results of the patient group are compared to those of the control group. This is seen as an appropriate and attainable strategy to determine abnormal patterns of performance in aphasic patients and to interpret these deviances in terms of our current knowledge about the processing of noun-verb ambiguities in a syntactic context (see also footnote 7 in chapter 4).

Experiments 1a and 1b test the selection of the syntactically appropriate reading of noun-verb ambiguities at the short 100 msec ISI between ambiguous words and targets. Experiments 2a and 2b do the same at the long ISI of 750 msec.

Experiment 1a

Method

Subjects
Forty-eight subjects from the subject pool of the Max Planck Institute for Psycholinguistics, most of them students at the University of Nijmegen, participated in Experiment 1a. All subjects were native speakers of Dutch. They were paid for their participation.

Materials
Forty ambiguous words with two unrelated meanings belonging to a different form class were selected from a list of Dutch words with multiple meanings (see chapter 2). For each of these noun-verb ambiguities, a set of four context sentences was constructed. The four context sentences formed two pairs. One pair consisted of sentences with a constituent structure that allowed the sentence-final word to be a noun, but not a verb. In the other pair, the sentence-final word could be a verb, but not a noun. Both sentences of these context pairs were identical up to the sentence-final word. In one member of the pair, the sentence-final word was one of the forty ambiguities, in the other member the sentence-final word was an unambiguous noun or verb. The unambiguous nouns and verbs were matched for length and frequency with the ambiguous nouns and verbs they replaced. Sentences ending with an unambiguous word served as the controls for their counterparts ending in an ambiguous word. An example of such a context quadruple is given below, with the sentence-final words

(i.e., the ambiguity and its controls) in capitals.[4]

N-bias: *Het meisje heeft moeite met de meeste TONEN.*
Control: *Het meisje heeft moeite met de meeste SOMMEN.*

V-bias: *De man wist nog niet wat hij zou gaan TONEN.*
Control: *De man wist nog niet wat hij zou gaan KOKEN.*

The sentences were semantically neutral. That is, the context did not bias a specific reading of the ambiguity on the basis of the semantic information it contained. In general, the context sentences up to the final word, although not unnatural, were very unspecific in their content. None of the content words in the context were in any way semantically or associatively related to the sentence-final word (the prime) or to the target word following the presentation of the sentence. In this way, it was assured that the contextual bias in the direction of either reading of the ambiguity was almost exclusively due to the syntactic constraints of the context. The context bias, thus, has its effect via the form class (i.c. noun or verb) associated with the appropriate reading of the ambiguous word.

Pretests

The total set of 160 sentences (4x40) was first tested with a cloze procedure. The cloze test contained all the sentences with the exception of the sentence-final word. Because the four context sentences for each ambiguous word consisted of two pairs that were identical up to the final word, the cloze test contained a total of 80 sentences, presented in a random order with the final word left out. This cloze test was given to twenty-eight subjects from the MPI subject pool, who were paid for their participation. Subjects were instructed to fill in one word that fitted the context. In order to get sentences without a semantic bias for the final word, the cloze probability for the sentence-final words should be zero. However, to assure that the syntactic context constraints were adequate, the responses given by the subjects should be within the appropriate form class in the large majority of the cases. The results of this cloze test led to the revision of the items that did not fit these criteria. Problematic items entered a cycle of revision and further cloze tests until a sufficient number met the criteria.

An association test was performed on the materials that resulted from the cloze tests. This association test presented the context sentences, including the sentence-final words, to another group of subjects. These subjects were required to read the sentences and to write down the first word that came to mind upon reading the final word of the sentence. This test was done to establish whether the context was successful in biasing the intended reading of the ambiguous words. For the control sentences, the results should confirm the absence of a semantic relation between prime and target, in that the target word must never be given as a response. Two versions of the association test were constructed. The members of a pair of context sentences were distributed across the two versions. The two context sentences sharing their sentence-final ambiguity were also allocated to different versions. Thus, the context sentence biasing the noun reading of an ambiguous word and the control sentence for the context biasing its verb reading were assigned to one version of the association test. The control sentence for the noun reading and the sentence biasing the verb reading were assigned to the other version. In this way each subject saw every ambiguous word and each context sentence only once. Each version of the association test was given to a different group of twenty subjects from the MPI subject pool. The subjects were paid for their participation.

The selected material

This series of pretests resulted in a set of 32 noun-verb ambiguities with their respective context sentences. The cloze probability of the sentence-final word was zero for all context sentences. The context sentences had a mean length of 8 words (range: 5-12).

The set of target words was selected from a list of associates to Dutch words with two or more unrelated meanings (see chapter 2), complemented with a few targets selected from the responses on the association test. Targets were the highest associates among the responses to the required reading of the ambiguity. The mean association strength of the target words was 43.8% (range: 14-91). None of the targets was given as a response in the cloze test.

For 16 of these 32 noun-verb ambiguities, a target word was chosen that related to the noun reading of the ambiguity. For the remaining 16 noun-verb ambiguities, the selected target word was associatively related to their verb reading. For the two groups of 16 ambiguities, the frequencies of both readings were established on the basis of Dutch frequency norms for a corpus of 720,000 words (Uit den Boogaart, 1975). In the group of noun-related targets, the verb readings had a slightly higher mean frequency than the noun readings: 40.4 for the noun readings (range: 0-259), and 60.3 for the verb readings (range: 0-307). In the group of verb-related targets, the noun readings had a higher mean frequency than the verb readings: 58.1 (range: 0-451) and 38.7 (range: 3-321) respectively.

The 32 selected target words were combined with the four context sentences, resulting in a concordant condition and its control, and a discordant condition with its control condition. For the set of noun-related targets, the concordant condition biased the noun reading of the ambiguous words, while their verb reading was biased in the discordant context. For the set of verb-related targets it was just the opposite: the concordant condition biased the verb reading, and the discordant condition biased the noun reading. Examples of the sentence-target combinations are presented in Table 1. The full set of the critical word target items is given in Appendix 4.[5]

TABLE 1

Examples of the sentences and target words in each condition. The sentence-final primes and the target words are in capitals.

Context Condition	Sentence	Target Word
	Target Type: Noun-related	
Concordant:	*In totaal bevestigde hij wel twaalf KLINKEN.*	*DEUR*
Control:	*In totaal bevestigde hij wel twaalf KNOPEN.*	*DEUR*
Discordant:	*Men verwacht daarop te kunnen KLINKEN.*	*DEUR*
Control:	*Men verwacht daarop te kunnen GOKKEN.*	*DEUR*
	Target Type: Verb-related	
Concordant:	*In de haast had hij het vergeten te SCHUREN.*	*SLIJPEN*
Control:	*In de haast had hij het vergeten te WASSEN.*	*SLIJPEN*
Discordant:	*Overal zie je hier tegenwoordig grote SCHUREN.*	*SLIJPEN*
Control:	*Overal zie je hier tegenwoordig grote LEUZEN.*	*SLIJPEN*

The context bias for the sentences with a sentence-final ambiguity was computed from the results of the association test. This was done by scoring the number of responses related to either meaning of the noun-verb ambiguities. For the set of the noun-related items, 90% of the responses to the ambiguous words in the concordant context sentences was in the intended direction (i.e., the noun reading), and 4% was in the non-intended direction (i.e., the verb reading). Responses to the same ambiguous words in the discordant context were in the intended direction (i.e., the verb reading) in 83% of the cases, and in the non-intended direction (i.e., the noun reading) in 7% of the cases. The contextual bias for the set of verb-related items was as follows: on average 90% of the responses to the lexical ambiguities in the concordant context was in the intended direction (i.e., the verb reading), and 3% in the non-intended direction (i.e., the noun reading); 88% of the responses to the same ambiguities in the discordant context was in the intended direction (i.e., the noun reading), and 4% in the non-intended direction (i.e., the verb reading).[6] These results confirmed that the context sentences did indeed bias the intended reading of the ambiguous words.

In addition to the 32 critical word targets preceded by four types of context, a set of 32 nonword targets was constructed in a more or less similar way. Half of these nonword targets had pairs of context sentences ending with either a noun-verb ambiguity or its control. An example of this nonword target-sentence combination is given below.

N-bias:	*Met gemak tilde de vrouw de grote BAKKEN.*	*ZOEREN*
Control:	*Met gemak tilde de vrouw de grote STOELEN.*	*ZOEREN*
V-bias:	*De vrouw heeft uren staan BAKKEN.*	*ZOEREN*
Control:	*De vrouw heeft uren staan LIFTEN.*	*ZOEREN*

The remaining 16 nonword target items were constructed in the same way with the exception that sentences did not end with an ambiguous word, and that the sentence-final word was different for all four context sentences.

In addition, 72 filler items and 32 startup items were constructed. Half of the filler items consisted of a word target preceded by an unrelated context sentence. The other half consisted of a context sentence followed by a nonword target. The startup items likewise had an equal distribution of word and nonword targets.

The 360 stimulus sentences (4x32 Test, 4x32 Nonword-control, 72 Fillers, 32 Startup) were divided into four blocks, each containing 90 sentences. The four context sentences constructed for each of the 32 critical noun-verb ambiguities were distributed among the four blocks such that each block contained 4 exemplars of each context condition, for both target types. In this way the four context conditions and the two target types were equally represented within the four blocks, whereas the ambiguous words and the target words occurred only once per block. The assignment of the 32 nonword targets and their context sentences was submitted to the same restrictions. The 72 filler items were assigned to the four blocks such that each block contained 9 filler items with a word target and 9 with a nonword target. Within a block, the sentences were presented in a random order. Each block started with 8 startup items, 4 with a word target and 4 with a nonword target. Thus, each block consisted of 45 sentences with a word target and 45 sentences with a nonword target. The order of the blocks was counterbalanced resulting in four presentation versions.

In addition to the 360 sentences in the four experimental blocks, 32 practice items were constructed, 16 with a word target and 16 with a nonword target. The context sentences in the set of practice items did not contain noun-verb ambiguities.

All materials were spoken at a normal rate by a female speaker in a sound-proof booth. The stimuli were digitized with a sampling frequency of 20 kHz, and stored in a VAX 750 computer. A speech waveform editing system was used to add targets to their respective sentences. Identical targets were represented by the same physical token. A trigger pulse was placed concurrent with target onsets, and a warning signal preceded each sentence. The interval of silence (ISI) between sentence offsets and target onsets was 100 msec. Trials were separated by a 4-sec interval consisting of 2800 msec of silence, a 200 msec warning signal, followed by another 1000 msec of silence. Five test tapes were then constructed. One tape contained the practice items, each of the other tapes contained one of the four experimental blocks. The input to and the output from the computer were low-pass filtered with a cutoff frequency of 10 kHz.

Apparatus
The apparatus for the experiment consisted of a Revox B77 stereo tape recorder, a Miro GD laboratory computer, a pulse-read unit, two pairs of Sennheiser HD 224 closed headphones (one for the subject and another for the experimenter), and a response keyboard with a YES button and a NO button. The stimuli on the left channel of the tape were played binaurally to the subjects, while the trigger pulses on the right channel of the tape started a millisecond timer. The pulses were inaudible to the subjects. Reaction times and type of response (yes/no) were stored directly with the aid of the computer. The time-out was set to 2 seconds. Latencies longer than 2 seconds were automatically stored as missing values.

Procedure
Subjects were randomly assigned to one of the four presentation versions, with twelve subjects in each version. The subjects were tested individually in a single session lasting approximately 55 minutes. Subjects were seated in a sound-proof booth with the keyboard placed in front of them, pressing the YES button with the index finger of the right hand and the NO button with the index finger of the left hand. All subjects were right-handed.

Subjects were told that they would hear a series of sentences immediately followed by a real Dutch word or a nonword. They were instructed to listen to each sentence, and to respond to the following sound sequence as quickly as possible, by pressing the YES button if it was a word or the NO button if it was a nonword. To make sure that the subjects listened to the sentences, they were told that some questions on the content of the sentences would be asked at the end of the session. They were advised to pay close attention to the sentences without trying to actually memorize them. The subjects were then presented the tape with the practice items. After the practice tape, subjects were again told that it was important to respond as quickly as possible, but without losing accuracy. No further feedback was given during the test session. Subjects had a three minute period of rest before each of the four experimental blocks. At the end of the test session subjects were asked a few questions about the materials.

Results

For the analyses of variance, the eight sentence-target conditions were divided into three factors, each containing two levels: Target Type, Ambiguity, and Congruency. Target Type referred to whether the target was related to the noun reading or to the verb reading of the ambiguous word. Ambiguity referred to the status of the sentence-final word, being either ambiguous or unambiguous. Congruency referred to the relationship between sentence and target. The concordant sentences, which biased the target-related reading of the ambiguity, and their controls were considered congruent. The discordant sentences biasing the alternative reading, which was unrelated to the target, and their controls were considered incongruent.

Analyses of variance were performed on latency data and error data of the critical word target trials. Before analyses on the latency data were done, errors and missing values were replaced by the subject's median latency in the relevant condition. In all cases, separate Repeated Measures Analyses of Variance were performed, treating subjects and items (target words) as random factors. In the subject analysis, Subjects, Target Type, Ambiguity, and Congruency were completely crossed. In the item analysis, Items were nested within Target Type, but crossed with Ambiguity and Congruency. Analyses of the latency data were performed on the subject medians (in the subject analysis) or the target word medians (in the item analysis) for each condition. Analyses on the error data were performed on the number of errors per condition. The results of the subject analyses will be reported. Results of the item analyses will only be reported if significant effects in the subject analysis have a value of $p>.10$ in the item analysis, i.e., when the two analyses yield different results.

The most critical tests of the hypotheses under consideration were, however, the nonorthogonal planned comparisons made in addition to the complex analyses of variance. Four pairwise comparisons tested the differences between the biasing contexts and their respective baseline conditions.[7]

Latency analyses

Means of the subject median latencies for each sentence-target condition are presented in Table 2.

TABLE 2

Means of the median auditory lexical decision times as a function of Context Condition and Target Type (ISI=100 msec).

Target Type	Noun-related		Verb-related	
Context Condition	RT	d	RT	d
	Students (N=48)			
Concordant	564	60	609	60
Concordant Control	624		669	
Discordant	622	−7	680	17
Discordant Control	615		697	

Differences (d) are measured relative to the control conditions.

The overall ANOVA using the lexical decision latencies from all eight sentence-target conditions revealed a significant main effect of Target Type ($F(1,47)=384.61$, $MSe=819$, $p<.0001$). Lexical decision latencies were on average 58 msec shorter for the noun-related targets compared to the verb-related targets. The effect of Target Type was due to the difference in length between the noun-related and the verb-related targets. The noun-related targets had a mean length of 576 msec (range: 465-697), 67 msec less than the verb-related targets with a mean length of 643 msec (range: 512-854). This effect is irrelevant with respect to the issues related to the resolution of noun-verb ambiguity in a syntactic context.

In addition, significant main effects were obtained for Ambiguity ($F(1,47)=78.76$, $MSe=1286$, $p<.0001$), and Congruency ($F(1,47)=146.02$, $MSe=904$, $p<.0001$). The analysis also yielded a significant Target Type by Congruency interaction ($F(1,47)=23.95$, $MSe=597$, $p<.0001$), and a significant interaction between Congruency and Ambiguity ($F(1,47)=62.54$, MSe=1153, $p<.0001$). The latter interaction indicates that reliable facilitation only emerged in the concordant condition, in which context and target were related to the same reading of the ambiguity.

Planned pairwise comparisons revealed significant facilitation for the concordant context relative to its baseline, both for noun-related ($F(1,47)=91.17$, $p<.0001$), and for verb-related targets ($F(1,47)=50.90$, $p<.0001$). Moreover, the 17 msec advantage for verb-related targets in the discordant condition, relative to its baseline condition, was also significant ($F(1,47)=6.41$, $p<.05$). A comparison between the same conditions was not significant for the noun-related targets ($F(1,47)=1.28$, $p=.26$).

In summary, for both types of targets significant facilitation emerged for the contextually appropriate reading of the noun-verb ambiguities, while some facilitation was also obtained for the verb-related targets in the discordant context. The latter targets, however, showed a significantly larger amount of facilitation in the concordant context than in the discordant context, as was revealed by an ANOVA on the difference scores of targets in the concordant/discordant contexts and in their respective baseline conditions ($F(1,47)=38.35$, $p<.0001$).

Error analyses

Subjects' mean percentages of errors for each sentence-target condition are presented in Table 3. Errors were made on 2.6% of trials with critical word targets.

TABLE 3

Mean percentage of errors (and total number of errors) as a function of Context Condition and Target Type (ISI=100 msec).

Target Type	Noun-related	Verb-related
Context Condition		
	Students (N=48)	
Concordant	1.3 (10)	2.5 (19)
Concordant Control	3.6 (28)	3.1 (24)
Discordant	1.3 (10)	4.4 (34)
Discordant Control	1.4 (11)	2.9 (22)

The overall ANOVA was performed on the number of errors for the eight sentence-target conditions. The effect of Target Type was significant in the subject analysis (F(1,47)=6.97, MSe=0.60, p<.05), but not in the item analysis (p=.14). More errors were made on trials with verb-related targets. No other significant main effects were obtained. The Target Type by Congruency interaction was significant (F(1,47)=6.15, MSe=0.38, p<.05), as was the Congruency by Ambiguity interaction (F(1,47)=5.72, MSe=0.53, p<.05). The Target Type by Ambiguity interaction was significant in the subject analysis (F(1,47)=6.37, MSe=0.28, p<.05), but not in the item analysis (p=.11).

Planned comparisons yielded a significant difference between the concordant condition and the appropriate baseline for the noun-related targets (F(1,47)=9.00, p<.005), but not for the verb-related targets (F<1). Less errors were made in the concordant context. The difference in the error scores of the discordant context and its baseline was not significant for the noun-related targets (F<1). For the verb-related target, however, this difference was found to be marginally significant (F(1,47)=3.81, p=.06). In the latter case, more errors were made on the verb-related targets in the discordant context than in the baseline condition. This effect qualifies the 17 msec latency advantage for the same targets in the discordant context. The faster RTs in this condition were accompanied by a higher number of errors. This suggests that the obtained facilitation was due to a trade-off in speed and accuracy. The other results of the analyses on the error data in no way contradict the pattern of results for the latency data.

In summary, reliable facilitation was only seen in the concordant condition where the context biased the target-related reading of the noun-verb ambiguities.

Most subjects were aware that some targets were repeated, and some subjects reported that they had been aware of the presence of ambiguous words. To check whether the repetition of targets and ambiguous words might have induced subjects to adopt special strategies, analyses were performed on the data from the first block presented to the subjects. Recall that within a block targets and ambiguous words were never repeated. Each of the four blocks occurred first in one of the four presentation versions. As a result, all of the items used in the experiment were included in the first-block analyses.

After the experiment, it turned out that two items each belonging to a different target type had been interchanged during the assignment of test items to the four blocks. This resulted in an unequal distribution of the context types over the target types in each of the four blocks. To correct this imbalance, the results on these items were treated as missing values in the first-block analyses.

A first-block ANOVA on the latency data yielded significant main effects of Target Type ($F(1,47)=150.34$, $MSe=4069$, $p<.0001$), Ambiguity ($F(1,47)=24.96$, $MSe=4446$, $p<.0001$), and Congruency ($F(1,47)=22.66$, $MSe=2839$, $p<.0001$; but not significant in the item analysis: $p=.11$). The Congruency by Ambiguity interaction was also significant ($F(1,47)=24.65$, $MSe=4038$, $p<.0001$). This interaction emerged because facilitation only occurred in the concordant condition. No other interactions approached significance.

Planned comparisons revealed facilitation of targets in the concordant context relative to its baseline, both for noun-related ($F(1,47)=32.93$, $p<.0001$), and for verb-related targets ($F(1,47)=24.50$, $p<.0001$). However, no significant differences existed between the discordant sentences and their controls (both $Fs<1$).

A first-block ANOVA on the error data yielded only a significant Target Type by Congruency interaction ($F(1,47)=9.28$, $MSe=0.18$, $p<.005$), which was not significant in the item analysis ($p=.50$). No other significant differences emerged.

Planned comparisons revealed that for neither target type significant differences emerged between the concordant or discordant sentences and their respective controls (all four $Fs<1$).

Since the pattern of results for the first-block analyses is highly similar to the one in the overall analyses, in that only reliable facilitation is obtained for targets in the concordant context, it is most likely that the pattern of results was not influenced by the repetition of targets and ambiguous words.

Discussion

The findings in Experiment 1a indicate that syntactic context information can be used very rapidly in selecting the contextually appropriate reading of noun-verb ambiguities. Previous studies (Seidenberg et al., 1982; Tanenhaus et al., 1979) have shown that initially both meanings of noun-verb ambiguities get accessed, following which contextual information rapidly (i.e., within 200 msec) integrates the contextually appropriate reading and suppresses the inappropriate one. The results support the claim that rapid contextual selection occurs on the basis of syntactic information contained by the context. The semantic information in the sentences was not specific enough to allow rapid selection of either meaning of the ambiguity. Selection of the contextually appropriate meaning, therefore, occurred via the selection of the contextually appropriate form class. This presupposes the on-line computation of structural constraints, which enable the selection of the appropriate form class(es) for the upcoming word.

Experiment 1b

The central question of this study is whether Broca's aphasics are able to use the syntactic information on-line during the process of language comprehension to select the appropriate reading of noun-verb ambiguities. If they can perform with the same efficiency as the younger normal subjects in Experiment 1a, the Broca's aphasics will also show selective facilitation of targets related to the syntactically appropriate reading of noun-verb ambiguities. If, in contrast, syntactically based selection does not occur or is relatively delayed in Broca's aphasics, multiple activation of both readings will result, irrespective of the syntactic bias.

Method

Subjects
Eight Broca's aphasics and twelve neurologically unimpaired elderly subjects participated in this experiment. The latter subjects served as the control group. All patients and ten of the twelve control subjects were right-handed. Patients were diagnosed on the basis of both their AAT-results and the rating of a spontaneous speech sample by three staff members of the Aphasia Project at the Max Planck Institute. All aphasic patients were unanimously classified as Broca's aphasics, and were clearly agrammatic in their spontaneous speech. Patients' age, gender, results on the Token Test, and their scores on the AAT-subtest on comprehension are specified in Table 4. All patients became aphasic as result of a CVA in the left hemisphere. At time of testing the mean post onset was 5.5 years (range: 2-9). The normal control subjects were approximately matched in age and education with the aphasic patients. The mean age of the Broca's aphasics was 58 years (range: 25-69), and the mean age of the normal control subjects was 58 years (range: 44-73).

Materials and Apparatus
Materials and apparatus were exactly the same as in Experiment 1a. The time-out was set to 3 seconds. Latencies longer than 3 seconds were automatically stored as missing values.

TABLE 4

Patient information

Patient	Age	Sex	Token Test*	Comprehension** Score AAT	Audit. Compr. Score AAT
01 Broca	59	m	2	93/120	51/60
02 Broca	69	f	20	90/120	43/60
03 Broca	55	m	37	73/120	43/60
04 Broca	25	m	34	100/120	54/60
05 Broca	63	m	24	76/120	42/60
06 Broca	60	f	9	98/120	47/60
07 Broca	64	m	46	90/120	46/60
08 Broca	61	m	21	102/120	54/60

* Scores on the Token Test are corrected for age. Severity of the disorder as indicated by the Token Test: no disorder (0-3); light (4-10); middle (11-33); severe (>33).

** Severity of the comprehension disorder as indicated by the AAT subtest Comprehension (includes word and sentence comprehension in both auditory and visual modality): severe (0-59); middle (60-89); light (90-104); no disorder (105-120).

Ranges of severity are based on the norms for the German version of the AAT.

Procedure

The twelve normal control subjects and the eight Broca's aphasics were assigned randomly to the four presentation versions. Three control subjects and two aphasic patients were assigned to each of the four versions. The subjects were tested in a single session of approximately five quarters of an hour, including short three minute breaks before the experimental blocks and a longer ten minute break after the second tape with test items. Subjects were seated in a quiet room diagonally across from the experimenter, with the keyboard placed in front of them.

Patients and elderly subjects were given similar instructions as the younger subjects in Experiment 1a, albeit in a less standardized form. They were required to use the special response procedure described in the previous chapters. In addition, they were told that during the test session the experimenter would stop the tape every now and then, and ask a question about the content of the preceding sentence. This was done to make sure that the subjects listened to the sentences. Questions were asked approximately five times per block. The questions were never asked on trials immediately preceding a critical sentence-target pair.

After the instruction the tape with practice trials was presented to familiarize the subjects with the procedure. If necessary, the instruction was given again and the practice trials were repeated until the experimenter was convinced that the subject understood the procedure. Before presenting the four blocks of test trials, the experimenter again emphasized the importance of both speed and accuracy. No further feedback was given during the test session.

Results

Replacement of errors and missing values (due to mechanical failures and time-outs), and the analyses on the latency data and on the error data were done according to the same procedures as in Experiment 1a. Separate analyses were performed for the data of the normal control subjects and the Broca's aphasics. Experiment 1a confirmed that the repetition of targets and ambiguous words did not influence the pattern of results. Therefore, only tests on the full set of data will be reported.

Latency analyses

The latency data for the normal control subjects and the Broca's aphasics are summarized in Table 5. For the group of normal control subjects the overall ANOVA yielded significant effects of Target Type ($F(1,11)=40.01$, $MSe=3004$, $p=.0001$), Congruency ($F(1,11)=6.16$, $MSe=2158$, $p<.05$), and Ambiguity ($F(1,11)= 7.82$, $MSe=3719$, $p<05$). The Target Type by Congruency interaction was significant in the subject analysis ($F(1,11)=11.8$, $MSe=701$, $p<.05$), but not in the item analysis ($p=.49$). No other interactions approached significance.

Planned comparisons yielded facilitation for targets in the concordant context relative to its baseline. This facilitation was significant for both noun-related targets ($F(1,11)=4.69$, $p=.053$), and verb-related targets ($F(1,11)=7.34$, $p<.05$). In contrast, the difference between the discordant contexts and their respective baseline conditions failed to reach significance for the noun-related targets ($F<1$), and for the verb-related targets ($F(1,11)=3.14$, $p=.10$). In summary, for the normal control subjects reliable facilitation was obtained for targets in the concordant context, but not in the discordant context.

The ANOVA on the latency data of the Broca's aphasics yielded marginally significant effects of Target Type ($F(1,7)=5.09$, $MSe=6499$, $p=.059$; in the item analysis: $p=.14$), Congruency ($F(1,7)=4.85$, $MSe=1184$, $p=.064$; in the item analysis: $p=.39$), and Ambiguity ($F(1,7)=5.11$,

TABLE 5

Means of the median auditory lexical decision times as a function of Context Condition and Target Type (ISI=100 msec).

Target Type	Noun-related		Verb-related	
Context Condition	RT	d	RT	d
	Normal Controls (N=12)			
Concordant	756	56	811	50
Concordant Control	812		861	
Discordant	787	4	864	29
Discordant Control	791		893	
	Broca's Aphasics (N=8)			
Concordant	803	78	896	46
Concordant Control	881		942	
Discordant	914	−43	873	67
Discordant Control	871		940	

Differences (d) are measured relative to the control conditions.

MSe=4331, p=.058). The analysis also obtained a marginally significant Congruency by Ambiguity interaction ($F(1,7)=5.03$, MSe=1962, $p=.06$). No other interactions approached significance.

Planned comparisons showed facilitation for noun-related targets in the concordant condition ($F(1,7)=6.46$, $p<.05$). Facilitation was also obtained for the verb-related targets in this condition ($F(1,7)=6.67$, $p<.05$). Noun-related and verb-related targets, however, behaved differently in the discordant context. For noun-related targets facilitation did not arise in the discordant context, as indicated by the 43 msec longer latency compared to the baseline ($F(1,7)=1.00$, $p=.35$) (see also Table 12, note 10). In contrast, facilitation did emerge for verb-related targets in the discordant context ($F(1,7)=15.56$, $p<.01$).

In conclusion, the pattern of results obtained for the Broca's aphasics deviates in one respect from that of the normal control subjects. Facilitation was obtained for the verb-related reading of noun-verb ambiguities, irrespective of the syntactic context bias. Although the control subjects showed a non-significant facilitatory trend for the verb-related targets in the discordant context, they clearly differed from the Broca's in that for these targets only the latter subjects showed a larger amount of facilitation in the discordant than in the concordant context.

Error analyses
The error data of the normal control subjects and the Broca's aphasics are summarized in Table 6.

TABLE 6

Mean percentage of errors (and total number of errors) as a function of Context Condition and Target Type (ISI=100 msec).

Target Type	Noun-related	Verb-related
Context Condition		
	Normal Controls (N=12)	
Concordant	1.0 (2)	2.1 (4)
Concordant Control	3.6 (7)	2.1 (4)
Discordant	4.2 (8)	3.1 (6)
Discordant Control	3.1 (6)	1.6 (3)
	Broca's Aphasics (N=8)	
Concordant	0.0 (0)	1.6 (2)
Concordant Control	5.5 (7)	2.3 (3)
Discordant	3.1 (4)	3.9 (5)
Discordant Control	4.7 (6)	4.7 (6)

The normal control subjects made errors on 2.6% of the trials with critical word targets. An ANOVA on the error data of the control subjects revealed that none of the main effects or interactions approached significance. Planned comparisons showed a significant difference between the error scores for the noun-related targets in the concordant condition and in the baseline ($F(1,11)=4.66$, $p=.054$), with more errors being made in the baseline condition. The other three comparisons did not yield significant differences. These results do not qualify the pattern of performance observed in the latency data.

The Broca's aphasics gave a nonword response on 3.2% of the critical word target trials. The overall ANOVA did not obtain any significant effect. Planned comparisons showed a marginally significant difference for the noun-related targets between the number of errors in the concordant condition and in the control condition ($F(1,7)=4.83$, $p=.064$). The other three comparisons did not reveal significant differences. These results do not qualify the pattern of results for the latency data as shown by the Broca's aphasics.

Discussion

The pattern of results for the normal control subjects is highly similar to the one obtained for the younger subjects in Experiment 1a. That is, reliable facilitation is only obtained for the concordant condition in which the context biases the target-related reading of the noun-verb ambiguities. Syntactic context information has been used to select the syntactically appropriate reading of the ambiguity within a time window of about 100 msec after the ambiguous word has been heard.

The pattern of results is partially different for the Broca's aphasics. Just like the normal younger and older subjects, these patients show facilitation for noun-related targets only in a context that syntactically biases the noun reading of the ambiguity. However, the situation is different for the verb-related targets. In the context biasing the noun interpretation, the verb reading was still fully activated. In contrast to the noun reading, the verb reading of the ambiguities was activated irrespective of the contextual bias. Within the time frame imposed by the experiment, context sentences biasing the noun reading of the ambiguous words did not succeed in suppressing the syntactically illegal verb readings. Contextual selection, thus, had occurred for the verb reading, but not for the noun reading.

The activation of verb readings in a context biasing the noun interpretation, cannot be attributed to a difference in the frequency of occurrence of both meanings. As was described in the materials section of Experiment 1a, the ambiguities in the set of verb-related items had noun readings that were on average slightly more frequent than their verb readings. Nevertheless, the less frequent verb readings were activated even in sentences biasing the more frequent noun readings. So, activation of the verb readings occurred despite a possible influence of meaning dominance in the opposite direction.[8]

A possible explanation relates to the morphological asymmetry between the verb and the noun readings. In the set of verb-related items, 13 of the 16 noun-verb ambiguities were presented in the citation form of the verb (i.e., the infinitive), while only 5 of these ambiguities had the citation form of the noun (i.e., the nominative singular). In most cases (e.g., *gebieden*), however, the ambiguous word referred to the citation form of the verb (i.e., the infinitive) and to a non-citation form of the noun (i.e., the plural). In Dutch both forms are morphologically complex, consisting of a stem and the affix *-en*. However, in terms of a markedness hierarchy, there is a clear difference. The verb-infinitive is the most unmarked form (Lapointe, 1985). In the markedness ranking, the plural form of the noun in Dutch is more marked than the verb infinitive. In the former case the *-en* ending marks for number. On the verb-infinitive, however, this suffix does not mark for tense or person.

There is a substantial amount of evidence that in their language production agrammatic patients have a tendency to substitute the unmarked verb infinitive for verb forms marked for person and tense (Lapointe, 1985; Goodglass & Geschwind, 1976). A similar kind of tendency might occur in language comprehension, in that these patients could have an (initial) preference to assign a word form its most unmarked interpretation. As a result, the unmarked reading of the noun-verb ambiguities is more difficult to suppress on the basis of syntactic context information than the marked reading. Suppressing the unmarked reading requires the on-line exploitation of specific information (i.c. number) associated with the inflectional suffix. Activation of both lexical meanings probably results from access to the stem morpheme (Tyler & Marslen-Wilson, 1986). Selection of the syntactically appropriate reading, however, can only be based on the access to and the integration of the suffixal information. Therefore, impairments in processing the syntactic information of the suffix are to be inferred from the absence of contextual selection.[9]

One possible account for these findings is that Broca's aphasics can no longer fully access or integrate the syntactic properties of inflectional suffixes (Tyler & Cobb, 1987). This account predicts that even when the patient is given more time, s/he will not be able to suppress the unmarked reading. Suppression of the unmarked reading presupposes the integration and selection of the marked reading. This requires that the syntactic implications of the inflectional morpheme can be identified for the marked interpretation of the ambiguity. Experiment 2b should reveal whether access to or integration of number information, specified by the inflectional suffix, is no longer possible, or whether it is relatively delayed in the Broca's aphasics.

A delay in the availability of the number information associated with the inflectional suffix also correctly predicts the obtained asymmetry. That is, as long as the information associated with this class of bound morphemes has not yet been made fully available or has not yet been integrated, syntactic context information cannot suppress the inappropriate but less marked interpretation of the ambiguity. In this case multiple activation of both the contextually appropriate and the contextually inappropriate reading will emerge.

In Experiments 2a and 2b the ISI between the ambiguity and its probe is increased from 100 msec to 750 msec. For the younger and older control subjects the same pattern of results is expected as in the Experiments 1a and 1b. They already had selected the contextually appropriate reading at the short ISI. So, they should do the same when given more time. If Broca's aphasics are delayed in completing this selection/integration process, they should show the normal pattern of performance at the longer ISI, since by then they have had sufficient time for the completion of contextual selection. If, in contrast, they cannot access or integrate the syntactic aspects of inflectional suffixes at all, the same results should be obtained as in Experiment 1b.

Experiment 2a

In Experiment 2a, a group of younger subjects is tested on the same materials as in Experiment 1a, but with a longer interval between sentence offset and target onset. The results of this experiment should support the theoretical framework within which the performance of the Broca's aphasics and their neurologically intact controls can be interpreted.

Method

Subjects
Forty-eight subjects from the MPI subject pool, mainly students, participated in Experiment 2a. All subjects except one were right-handed. All were native speakers of Dutch, and were paid for their participation. None of the subjects had participated in Experiment 1a.

Materials
The same materials were used as in Experiment 1a, with one important change. With the help of a speech waveform editing system, the ISI between sentence offsets and target onsets was increased to 750 msec.

These materials were then recorded onto five new test tapes. One tape contained the practice items, the other four tapes contained the four blocks of test items. The output from the computer was low-pass filtered with a cutoff frequency of 10 kHz. Apparatus and procedure were the same as in Experiment 1a.

Results

Errors and missing values were replaced in the same way as in Experiment 1a. Analyses on latency and error data were performed according to the procedures specified for Experiment 1a.

Latency analyses
Table 7 summarizes the latency data for the eight sentence-target conditions.

TABLE 7

Means of the median auditory lexical decision times as a function of Context Condition and Target Type (ISI=750 msec).

Target Type	Noun-related		Verb-related	
Context Condition	RT	d	RT	d
	Students (N=48)			
Concordant	594	53	641	55
Concordant Control	647		696	
Discordant	631	10	692	15
Discordant Control	641		707	

Differences (d) are measured relative to the control conditions.

The overall ANOVA on the medians per condition revealed significant main effects of Target Type ($F(1,47)=221.73$, $MSe=1360$, $p<.0001$), Ambiguity ($F(1,47)=104.35$, $MSe=1032$, $p<.0001$), and Congruency ($F(1,47)=46.78$, $MSe=1102$, $p<.0001$). Significant interactions were obtained between Target Type and Congruency ($F(1,47)=5.57$, $MSe=985$, $p<.05$; but not significant in the item analysis: $p=.45$), and between Congruency and Ambiguity

($F(1,47)=46.19$, $MSe=906$, $p<.0001$). The latter interaction is due to a differential effect for the concordant and the discordant context, relative to their respective baseline conditions. Inspection of Table 7 shows that the amount of facilitation is larger in the concordant contexts.

Planned comparisons yielded significantly shorter latencies in the concordant context sentences relative to their baseline conditions, for noun-related ($F(1,47)=63.23$, $p<.0001$), and for verb-related targets ($F(1,47)=73.36$, $p<.0001$). The differences between the discordant sentences and their controls of 10 msec and 15 msec for noun-related and verb-related targets respectively, were also shown to be significant (for the noun-related targets: $F(1,47)=5.05$, $p<.05$; for the verb-related targets: $F(1,47)=6.73$, $p<.05$). An ANOVA on the difference scores between the concordant/discordant sentences and their respective controls confirmed that the facilitation was much larger in the concordant condition than in the discordant condition ($F(1,47)=111.14$, $p<.0001$).

In summary, both target types showed a large amount of facilitation in the concordant context, and a much smaller but still significant amount of facilitation in the discordant context.

Error analyses

A summary of the error data is presented in Table 8. Errors were made on 1.5% of the critical word target trials. The overall ANOVA yielded a significant effect of Target Type in the subject analysis ($F(1,47)=8.56$, $MSe=0.24$, $p<.01$), but not in the item analysis ($p=.20$). More errors were made on trials with verb-related targets than on trials with noun-related targets. The effect of Congruency was significant in the subject analysis ($F(1,47)=5.35$, $MSe=0.16$, $p<.05$), but not in the item analysis ($p=.20$). More errors were made on incongruent than on congruent targets. No other main effects or interactions were significant.

Planned comparisons revealed that both target types did not have significant differences in the number of errors between the concordant/discordant contexts and their respective controls. In conclusion, the pattern of results for the error data in no way contradicts that of the latency data.

To exclude the possibility of confounding effects due to the repetition of the critical target words and the noun-verb ambiguities, analyses were also performed on the first-block data only. For these analyses the same procedures applied as in Experiment 1a.

The first-block ANOVA on the latency data showed significant effects of Target Type ($F(1,47)=141.73$, $MSe=5249$, $p<.0001$), and Ambiguity ($F(1,47)=11.20$, $MSe=4175$, $p<.005$). The analysis also yielded a significant Congruency by Ambiguity interaction ($F(1,47)=18.15$, $MSe=3096$, $p=.0001$;

TABLE 8

Mean percentage of errors (and total number of errors) as a function of Context Condition and Target Type (ISI=750 msec).

Target Type	Noun-related	Verb-related
Context Condition		
	Students (N=48)	
Concordant	0.8 (6)	1.4 (11)
Concordant Control	1.0 (8)	1.4 (11)
Discordant	0.9 (7)	2.0 (15)
Discordant Control	1.3 (10)	2.9 (22)

but not significant in the item analysis: $p=.14$).

Planned comparisons revealed significant facilitation in the concordant contexts relative to their controls, for both noun-related targets ($F(1,47)=11.68$, $p<.005$) and verb-related targets ($F(1,47)=14.53$, $p<.0005$). However, the same targets did not show any facilitation in the discordant condition (both $Fs<1$).

A first-block ANOVA on the error data yielded a significant effect of Target Type in the subject analysis ($F(1,47)=4.58$, $MSe=0.11$, $p<.05$), but not in the item analysis ($p=.65$). No other significant effects were obtained. Planned comparisons showed that for both target types, the number of errors in the concordant and discordant contexts did not differ from the number of errors in their respective controls (all four $Fs<1$).

The pattern of results for the first-block analyses differed in only one respect from that of the overall analyses. In the first-block analyses no facilitation was obtained for targets in the discordant contexts, while the overall analyses did obtain some facilitation in these contexts. It cannot be excluded that this relatively small amount of facilitation is due to the repetition of ambiguities and targets. These effects should, therefore, be interpreted with some caution.[10] However, with respect to the effects of context, both overall analyses and first-block analyses revealed a similar pattern of results, in that substantial facilitation only emerged in a congruent context. The interpretation of the context effects is most critical for the issues addressed in this study. These effects, at least, do not seem to be confounded by the repetition of targets and noun-verb ambiguities.

Discussion

As expected, the results of Experiment 2a confirm those of Experiment 1a. The syntactic information of the sentence aids in the selection of contextually appropriate lexical meanings. Evidence for the contribution of syntactic information to the integration of lexical meanings into a higher-order message representation was already obtained at an ISI of 100 msec, and is further supported by the results of this experiment. Not only semantic but also syntactic context information seems to play an essential role in the rapid, on-line integration and selection of contextually appropriate lexical meanings during the process of language comprehension.

Experiment 2b

Experiment 2b was performed to see whether at a longer ISI the Broca's aphasics will show the normal pattern of contextual selection. The previous chapter showed that these patients are relatively delayed in selecting lexical meanings on the basis of sentential-semantic context information. If a similar delay holds for selection on the basis of syntactic context information, this experiment should show the same pattern of results for the normal control subjects and the Broca's aphasics, even though in part they performed differently from each other in Experiment 1b.

Method

The same eight Broca's aphasics as in Experiment 1a, and another group of twelve neurologically unimpaired control subjects participated in Experiment 2b. Ten of these control subjects were right-handed and two were left-handed. The normal control subjects were approximately matched in age and education with the aphasic patients. Their mean age was 53 years (range: 33-63). For the aphasic patients, the time interval between the previous test session and the time of testing in Experiment 2b was at least three weeks.

Materials and apparatus were the same as in Experiment 2a. The procedure was identical to the one in Experiment 1b.

Results

In analyzing the results the same procedures were used as in Experiment 1b. The results for the normal control subjects and the Broca's aphasics were analysed separately.

Latency analyses
Table 9 summarizes the latency data for both groups of subjects. For the normal control subjects, the overall ANOVA yielded significant effects of Target Type ($F(1,11)=60.99$, $MSe=1311$, $p<.0001$), and Ambiguity ($F(1,11)=14.96$, $MSe=1297$, $p<.005$). The effect of Congruency was only marginally significant ($F(1,11)=3.72$, $MSe=2349$, $p=.08$).

TABLE 9

Means of the median auditory lexical decision times as a function of Context Condition and Target Type (ISI=750 msec).

Target Type	Noun-related		Verb-related	
Context Condition	RT	d	RT	d
	Normal Controls (N=12)			
Concordant	745	51	798	67
Concordant Control	796		865	
Discordant	794	−2	849	−3
Discordant Control	792		846	
	Broca's Aphasics (N=8)			
Concordant	817	21	833	46
Concordant Control	838		879	
Discordant	826	5	887	−3
Discordant Control	831		884	

Differences (d) are measured relative to the control conditions.

In addition, a significant Congruency by Ambiguity interaction was obtained ($F(1,11)= 16.69$, $MSe=1355$, $p<.005$), indicating that facilitation only occurred when context and target were congruent. No other interactions approached significance.

Planned comparisons revealed that lexical decision latencies were only shorter in the concordant context relative to the appropriate control sentences, for both the noun-related targets ($F(1,11)=11.27$, $p<.01$) and the verb-related targets ($F(1,11)=15.89$, $p<.005$). The differences between the two target types in the discordant contexts and their respective baseline conditions were not significant (both $Fs<1$).

In conclusion, the normal control subjects only showed facilitation in the concordant context, which biased the target-related reading of the ambiguous word.

The overall ANOVA on the latency data of the Broca's aphasics yielded a significant effect of Target Type ($F(1,7)=16.05$, $MSe=1807$, $p<.01$). No other significant main effects or interactions were obtained.

Planned comparisons revealed that the 21 msec shorter latency for the noun-related targets in the concordant condition relative to its baseline, failed to reach significance ($F<1$). Inspection of the individual subject data, however, revealed that the absence of a significant facilitation effect in this context was due to one patient. Seven of the eight patients had shorter latencies in the concordant context than in the appropriate control condition. One patient had a 123 msec longer latency in the concordant context relative to the control. Analyzing the data after the exclusion of this single patient, led to a highly significant facilitation of 43 msec for the remaining seven patients ($F(1,6)=27.95$, $p<.005$).[11]

A planned comparison testing the difference between the verb-related targets in the concordant condition and the baseline, yielded a significant facilitation of 46 msec ($F(1,7)=6.00$, $p<.05$). After the exclusion of the patient with a deviant pattern of performance, a 32 msec facilitation remained which was marginally significant ($F(1,6)=4.82$, $p=.07$).

The difference between the discordant context and its baseline, however, did not approach significance for either target type (both $Fs<1$). This pattern of results did not change after removing the deviant patient from the analyses (both $Fs<1$).

In summary, apart from one patient the Broca's aphasics showed the normal pattern of results. That is, facilitation only occurred when syntactic context and target were congruent.

Error analyses

The error data of both groups of subjects are summarized in table 10. The normal control subjects made errors on only 1.0% of the trials with critical word targets. The overall ANOVA on the error data of the normal control subjects showed that none of the main effects or interactions approached significance. Planned comparisons did not reveal significant differences for either target type. In conclusion, the restricted numbers of errors for the normal controls were equally distributed over the eight sentence-target conditions. Thus, the error data do not further qualify the interpretation of the latency data.

TABLE 10

Mean percentage of errors (and total number of errors) as a function of Context Condition and Target Type (ISI=750 msec).

Target Type	Noun-related	Verb-related
Context Condition		
	Normal Controls (N=12)	
Concordant	1.0 (2)	0.5 (1)
Concordant Control	1.0 (2)	0.0 (0)
Discordant	0.5 (1)	1.6 (6)
Discordant Control	2.1 (4)	1.6 (6)
	Broca's Aphasics (N=8)	
Concordant	0.8 (1)	2.3 (3)
Concordant Control	2.3 (3)	2.3 (3)
Discordant	1.6 (2)	3.9 (5)
Discordant Control	3.1 (4)	3.1 (4)

The Broca's aphasics made errors on 2.4% of the critical word target trials. The overall ANOVA did not yield any significant effect. Planned comparisons also did not reveal significant differences between the concordant or discordant contexts and their respective controls, neither for targets related to the noun reading nor for those related to the verb reading of the ambiguous words. As was the case for the normal control subjects, the error data of the Broca's aphasics do not further qualify their pattern of results for the latency data.

Discussion

As expected, the pattern of results for the normal control subjects is essentially the same as in Experiment 1b. That is, reliable facilitation is only obtained for the reading of the ambiguity that is biased by the syntactic context information. Selection of the syntactically appropriate reading of the ambiguous words has been completed very rapidly after the noun-verb ambiguities have been heard.

More surprising are the results for the Broca's aphasics. The group of patients showed essentially the normal pattern of performance. For both noun-related and verb-related targets facilitation was only obtained if the context biased the form class of the reading that was probed by the target. This implies that contextual selection on the basis of syntactic context information has been completed at the ISI of 750 msec. These results support the view that Broca's aphasics can access and integrate syntactic information associated with inflectional suffixes. However, the absence of contextual selection for the noun readings within the time frame imposed by the ISI of 100 msec, suggests that they are delayed in the on-line exploitation of syntactic information during the construction of an interpretation for the utterance.

General discussion

In contrast to almost all the other on-line studies on the processing of syntactic information in aphasic patients (Baum, 1988, 1989; Hagoort, 1989a; Friederici & Kilborn, 1989; Shankweiler et al., 1989; Tyler, 1985, 1989; Tyler & Cobb, 1987), this study did not tap the syntactic processor by measuring its sensitivity to grammatical violations. Instead, subjects had to compute at least a local structure to allow the selection of the contextually appropriate lexical meaning of words which have multiple meanings belonging to different form classes. Thus syntactic processing was measured via its contribution to the construction of a message representation of the utterance. The construction of this higher-level sentence representation requires the rapid incorporation of the syntactic and semantic implications of the morphemes being heard (Tyler & Marslen-Wilson, 1986). It is in the temporal aspects of using the syntactic implications of certain morphemes that Broca's aphasics showed a deviant pattern of performance. Table 11 summarizes the pattern of facilitation for the Broca's aphasics at both ISIs. As can be seen, they showed the normal pattern of results at the long ISI. That is, facilitation only emerged if the contextual bias and the target type were related to the same reading of the ambiguity. At the short ISI, however, facilitation was also obtained for verb-related targets in a noun-biasing context. This pattern of results suggests a delay in lexical selection for a subset of the items. What is the underlying cause of this delay?

TABLE 11

Pattern of facilitation for the group of Broca's aphasics, as a function of ISI, Target Type, and Contextual Bias.

		ISI=100 msec		ISI=750 msec	
Target Type		N	V	N	V
Contextual Bias	N	+	+	+	–
	V	–	+	–	+

+: facilitation –: no facilitation

One possibility is a delay in the computation of phrasal structures. As a consequence, the constraining influence upon the form class of the upcoming word shows up later than normal, if at all. The data, however, do not provide any evidence for this explanation. A delay in the computation of phrasal structures should have an equal effect on the noun and the verb reading of the ambiguity. A priori, such an account does not predict that the constraining influence from the syntactic context will be delayed selectively or more strongly for phrases that prohibit a verb to occur, compared to phrases that prohibit a noun to enter the phrase structure. A slower-than-normal activation of phrasal nodes predicts facilitation at the ISI of 100 msec for all four combinations of target type and contextual bias. In other words, the asymmetry in the data between the selection of the noun and the verb reading at the short ISI cannot be explained by a general delay in the computation of phrasal nodes. A recent simulation model, however, assumes this to be the underlying cause of agrammatic sentence understanding (Haarmann & Kolk, 1988). The authors conclude from their simulation results that the temporal availability of phrasal categories is affected in agrammatic patients. Both a decrease in activation rate or an increase in decay rate of phrasal categories (e.g., NP, VP) are claimed to result in agrammatic comprehension. However, such an account cannot explain the findings of this study. The results suggest a deficit in the time course of morphosyntactic processing.

A more likely account focuses on the time course of accessing or integrating the syntactic aspects of closed class morphemes. Either the access or the integration of this information is delayed. This has the following consequences for the morphologically complex ambiguous words consisting of a stem and a suffix. On the basis of the stem, both readings of an ambiguous word are accessed. The syntactic context constraints do not seem to influence the identification of the stem, but rather the inflected full form via the syntactic information of the suffix (Tyler & Marslen-Wilson, 1986). Selection on the basis of syntactic context information can thus only take place at the moment that the syntactically specified suffixal information becomes integrated.

I would suggest that as long as this information has not been fully retrieved or has not yet been integrated into the message representation, suppression of the unmarked interpretation of the full form does not occur. In the case of the noun-verb ambiguities used in this study, the verb-infinitive was the unmarked form. Due to a delay in the activation or integration of the number information contained by the suffix *-en* in Dutch, suppression of the unmarked verb reading in a context with a syntactic bias towards a noun reading, did not occur at the short ISI. Only after the suffixal information had been fully accessed or integrated, did the syntactic context suppress the inappropriate reading of a noun-verb ambiguity.

According to Friederici (1988b), in Broca's aphasics the process of accessing syntactic information specified by closed class morphemes is delayed relative to the activation of lexical meanings. The results of this study are in agreement with this temporal mismatch account of syntactic processing deficits in Broca's aphasics.

However, the previous chapter showed a comparable delay in the selection of lexical meanings on the basis of sentential-semantic context information. This delay cannot be explained by the temporal mismatch view, since Friederici's account crucially predicts a selective delay in the access of syntactic information.

An alternative option is that integration processes are slower-than-normal, causing delays in the selection of both the semantically appropriate and the syntactically appropriate reading of ambiguous words. A general delay in the integration of lexical information into a higher-level message representation results in a postponement of the selection of the appropriate reading on the basis of the contextual information, independent of whether this information is semantic or syntactic in nature. Given the lack of well-specified processing models of lexical integration, it is not possible to be very specific about the exact nature of a change in the temporal aspects of integration. One difference between lexical and higher-level representations is that the former ones are prestored and the latter ones have to be computed. The computation of higher-level representations out of the lexical ingredients, presumably requires some processing resources. A shortage in processing capacity might hamper an optimally efficient - that is very rapid - integration of lexical information with the computed representation of the context (cf. Caplan & Hildebrandt, 1988; see chapter 6).

6

CONCLUDING REMARKS

In this final chapter, the reported data will be brought to bear on a few central questions in aphasiology. This analysis will serve the purpose of further reducing the problem space for accounts of Broca's and Wernicke's aphasia.

The experimental studies only investigated Broca's and Wernicke's aphasics. The general claims I will make about the nature of the underlying impairment are based on the results for these two patient types. Because other patient types were not tested, for the moment it is an open question whether they apply equally to those or only to the types of aphasia that were investigated.

Is aphasia a knowledge deficit or a processing impairment?

In computing an interpretation from the speech input, listeners have to access and exploit different types of implicit knowledge. These knowledge structures are permanently stored in memory. They represent information about the form, meaning, internal structure, and syntax of words (e.g., their form class and thematic frames), but also about the grammatical principles that constrain the structural decisions of the processor. A model of the listener must not only specify these knowledge sources, but should also explicate how the language processor is designed such that its processing components can exploit the knowledge representations in real time, to map the acoustic-phonetic input onto a message representation.

Comprehension deficits in aphasic patients as revealed by clinical interviews or formal tests, indicate that this mapping is not completely successful, resulting in a message representation which is more or less inadequate vis à vis the input. In trying to determine the functional etiology of these deficits, one question to be answered is whether they are due to a loss of knowledge representations or to an impairment in one or more of the processing components.

The results presented in the previous chapters clearly point to a processing impairment. In chapter 3 significant overall semantic priming effects were reported for both Broca's and Wernicke's aphasics at the shorter intervals between primes and targets. These priming effects indicate a more or less normal access to the mental lexicon, and indicate that lexical-semantic representations are not lost and that the network structure of the semantic lexicon is not compromised. Especially for Wernicke's aphasics, previous studies have claimed that lexical-semantic deficits were caused by a loss in the representational structure of the semantic lexicon (e.g., Goodglass & Baker, 1976; Zurif et al., 1974). The results reported in chapter 3, however, showed that the locus of the deficit is in the processing system. As such they support the claims put forward in a number of previous priming studies with aphasic patients (e.g., Blumstein et al., 1982; Milberg & Blumstein, 1981).

Chapters 4 and 5 further emphasize the possibility of a processing deficit. Broca's aphasics could access both meanings of ambiguous words and use semantic as well as syntactic context information to select the contextually appropriate reading, albeit at a slower-than-normal rate. The results for the Wernicke's aphasics showed an indication of activation for both meanings of ambiguous words (cf. Swinney et al., 1989), but the semantic context information did not result in the selection of the biased reading. This latter result, however, could well be due to a processing deficit (see below). A loss of lexical and syntactic knowledge would not have led to the patterns of performance reported in chapters 4 and 5.

In conclusion, this thesis provides further empirical evidence for the claim that aphasic deficits, at least those in Broca's and Wernicke's aphasics, are more due to an impairment in one of the processing components than to a loss of stored knowledge representations (cf. Friederici, 1988a; Kolk & van Grunsven, 1985; Shankweiler et al., 1989).

What is the nature of the processing deficit?

Different proposals have been put forward with respect to possible processing impairments that might underlie comprehension deficits in aphasia. The three most important are phrased in terms of impairments in either automatic or controlled processing (Blumstein et al., 1982; Friederici, 1988b; Grodzinsky, Swinney, & Zurif, 1985; Milberg et al., 1987), in a limitation in computational resources (Caplan & Hildebrandt, 1988; Linebarger et al., 1983a), and in changes in the temporal organization of language processing (Friederici, 1988a; Kolk & van Grunsven, 1985; Swinney, Zurif, & Nicol, 1989). Although coined in different terms, it remains to be seen whether these proposals are really independent. In the following, I will evaluate each of them in the light of the reported results.

Automatic versus controlled processing

The computation of a message representation from the acoustic-phonetic input is a highly automatic, reflex-like process, in which the intermediate representations are normally neither subject to conscious control nor available to awareness. As such, most of the processing between the sensory input and the delivery of its interpretation has all the characteristics of automaticity: it is fast, it can occur in parallel with other processes, it does not interfere with other ongoing mental activities, and it does not require awareness (e.g., Flores d'Arcais, 1988; Marcel, 1983; Neely, 1977; Posner & Snyder, 1975; Shiffrin & Schneider, 1977). Whether automatic processing requires the allocation of resources is still a matter of debate. The strongest claim is that it does not (Shiffrin & Schneider, 1977). However, a probably more realistic alternative is that automatic processes have their own dedicated resources which are triggered by specific internal or external input events (Navon & Gopher, 1979).

Automatic processing is mostly defined by the opposite values for properties of controlled processing (cf. Logan, 1988). Controlled processing is rather slow, and under executive (or attentional) control. It is, moreover, open to awareness and it has to share its processing resources with other mental activities. All kinds of operations on the output representation of the comprehension process are forms of controlled processing. Relating the message representation to the listener's knowledge of the world is an example, but also the employment of the message representation in matching a sentence to a picture (a standard task in aphasiology).

Loss of automaticity, especially with respect to lexical access, has been claimed to underlie comprehension deficits in Broca's aphasia. However, closer inspection reveals that different authors subsume different claims under this heading. Grodzinsky et al. (1985) take it to mean that agrammatics are "slower and less elaborative" in the retrieval of lexical information, "thus providing a very different information base to the comprehension system of the agrammatic listener" (p. 78). No current definition of automatic processing lists elaboration as one of its properties. Only the slowed speed of processing can be seen as affecting automaticity.

However, slowed processing does not necessarily lead to a "very different information base". It is therefore difficult to attribute the notion of loss of automaticity to this description of the impairment.

Friederici (1988b) in her account of lost automaticity in agrammatic comprehension refers especially to the reduction in speed of processing. In contrast to normal subjects, Friederici found longer latencies in Broca's aphasics for closed class words than for open class words in a word monitoring task (Friederici, 1983, 1985). This has led her to amend the hypothesis that a special recognition device for closed class items is no longer available in Broca's aphasia (Bradley, 1978). According to Friederici, access to closed class words is no longer automatic. However, by this she clearly does not mean that access to closed class words in Broca's aphasics is under conscious control or has to share its resources with non-linguistic processes. She, moreover, explicitly states that access to closed class words, although slowed down, remains informationally encapsulated from semantic context information. Autonomy of lexical access is thus retained (Friederici, 1988b). Loss of automaticity in this view is completely identical with loss of speed. In order to avoid possible confusions, it might be preferable to phrase this account of the nature of the impairment in terms of changes in the temporal organization of language processing events. In recent reformulations and refinements of her ideas (see below), Friederici has started to do so (Friederici, 1988a; Friederici & Kilborn, 1989).

Milberg et al. (1987) have suggested a deficit in the automatic access to lexical-semantic information in Broca's aphasics on the basis of results in a number of priming studies (cf. Milberg et al., 1987). In chapter 3 I have extensively argued that this claim mainly rests on the incorrect assumption that priming effects obtained with a lexical decision task always and only reflect automatic processing. To validate this claim, one has to tap automatic activation spreading between related nodes in the semantic lexicon. It is generally assumed that this requires short intervals between primes and targets (Neely, 1977). To date none of the priming studies with aphasic patients has used intervals that were short enough to allow firm conclusions with respect to a possibly defective mechanism of automatic activation spreading. In my study reported in chapter 3, I used an interval between primes and targets that was short enough to tap automatic activation spreading. Clear priming effects were obtained for both Broca's and Wernicke's aphasics.

In conclusion, there is no empirical evidence that Broca's aphasics have lost their capacity to automatically access the mental lexicon. In addition, there is hardly any evidence that automaticity is lost at other levels of processing in the comprehension system of aphasic patients. There is, however, evidence for a loss of speed in processes involved in mapping the acoustic-phonetic input onto the message representation. But loss of speed is insufficient evidence for a loss of automaticity. Loss of automaticity implies that only controlled processing is possible. This requires that in addition to speed of processing, a whole series of other dichotomous properties has changed its value. The data do not indicate this to be the case.

The situation is different with respect to controlled processing of lexical-semantic information. The data suggest that controlled processing might be affected in Wernicke's aphasics, but possibly also in Broca's aphasics. One piece of evidence is the absence of priming effects at longer ISIs. Controlled processing in a priming paradigm has been said to indicate the integration of the lexical meaning within its context (De Groot, 1990; Seidenberg et al., 1984). At longer ISIs, associative and semantic priming effects depend more heavily or, in the absence of a contribution of expectancy, depend exclusively on the success of meaning integration. The data discussed in chapter 3 are consistent with the view that the locus of the impairment in lexical-semantic processing is at the level of post-lexical meaning integration, and not at the level of automatic activation spreading through the lexical-semantic network. This account of the impairment in lexical-semantic processing is in agreement with the recent claim that both hemispheres have the capacity to automatically access lexical-semantic representations, but that only the left hemisphere is engaged in controlled processing (Burgess & Simpson, 1988; Chiarello, 1985, 1988). A priori, a lesion in the left hemisphere thus seems to have a higher chance of affecting controlled, as opposed to automatic processing.

The results of the Wernicke's aphasics on an explicit memory task, however, suggest that controlled processing is not a unitary phenomenon. The performance of these patients dramatically deteriorates when they are asked to give metalinguistic judgements. They seem to fail most severely if they have to execute conscious operations on the output of lexical-semantic processing, whereas the performance of the Broca's aphasics is near normal under these task conditions. The overall picture emerging from the results of chapter 3 with respect to the Broca's and Wernicke's aphasics, indicates that specifications of the nature of aphasic impairments in terms of the dichotomy between automatic and controlled processing will most probably not provide us with a sufficiently fine-grained account of aphasic deficits. We have to search for other characterizations of the processing impairments in aphasic patients.

Computational resources

During the process of constructing a message representation from the speech input, intermediate results need to be stored in memory. Working Memory has been proposed as the storage place for intermediate representations (Baddeley, Vallar, & Wilson, 1987; Clark & Clark, 1977). However, both studies on patients with severe limitations in auditory-verbal short-term memory (Butterworth, Campbell, & Howard, 1986; Martin, 1987), and studies on the role of memory in aphasic deficits (Caplan, Vanier, & Baker, 1986) have failed to establish a substantial role for components of Working Memory (i.e., the phonological store and the articulatory loop) in either normal or impaired sentence comprehension. The role of Working Memory seems to be restricted to situations where a verbatim record of the sentence has to be consulted, for instance if a first-pass analysis failed. A more plausible proposal therefore is that intermediate results of sentence analysis are stored in one or more processor-specific stores (Butterworth et al., 1986; Caplan et al., 1986; Kolk & van Grunsven, 1985; for a comparable proposal in language production, see Levelt, 1989). The sentence processor thus stores the intermediate results from constituent structure assignments or thematic role assignments in its own 'processor-internal memory' (Caplan et al., 1986). Whether this processor-internal memory has to be further subdivided into separate buffers for the results of syntactic analysis, semantic analysis, etc., is an as yet completely unsettled issue.

Limitations in memory storage has been proposed as one of the possible processing impairments that cause comprehension deficits in aphasic patients (Caplan & Hildebrandt, 1988; Linebarger et al., 1983a, 1983b). Linebarger et al. (1983a) found that their agrammatic patients performed much better in a grammaticality judgement task than in sentence picture matching. In one of their explanations for the disparity in performance on these different tasks, they suggest a limitation in processing resources as the underlying impairment. Linebarger et al. assume that agrammatic patients "are capable of carrying out all the necessary operations to achieve a full parse of input sentences, but at greater effort and computational expense than is normally the case" (p. 388). Because in their view semantic processing has to draw from the same pool of resources as syntactic analysis, a grammaticality judgement task is less demanding than a sentence picture matching task, because the former does not require a full semantic interpretation of the input sentences. A sentence picture matching task testing semantically reversible sentences, however, requires both syntactic and semantic analysis.

Caplan and Hildebrandt (1988) have also proposed a limitation in computational resources as one of the causes for comprehension impairments in agrammatic patients. A major argument in support of this account is based on the sentence complexity effect. That is, performance has a higher probability of breaking down if sentences increase in syntactic complexity. According to Caplan and Hildebrandt, the sentence complexity effect should be attributed to a capacity limitation, since the same parsing operations that patients can perform in sentences of low complexity, can no longer be carried out when other operations have to be performed in addition. The latter state of affairs applies to more complex sentences.

Both Linebarger et al. (1983a) and Caplan and Hildebrandt (1988) seem to mainly associate the limitation in processing resources with a reduced efficiency in the execution of parsing operations, although they acknowledge the possibility that the 'parsing work space' may share processing resources with other memory systems involved in comprehension. The data reported in the previous chapters do not easily fit into an account that restricts a reduction in computational resources to parsing operations. The loss of semantic/associative priming effects at a relatively long interval between primes and targets (chapter 3) cannot be explained in this way, since establishing the semantic relation between isolated words does not involve parsing. Moreover, the delay obtained for Broca's aphasics (chapter 4) in using semantic context information to select the biased reading of an ambiguous word, is not easily explained by a limitation in processing resources that selectively affects the computation of syntactic relations among the major lexical items.

If a limitation of computational resources is (one of) the underlying causes of aphasic comprehension deficits, the reported data suggest that this limitation also affects the computation of other than syntactic representations from the speech input.

The delayed meaning selection in Broca's aphasics both in a sentential-semantic (chapter 4) and a syntactic (chapter 5) context, moreover, implies that if limitation in processing resources is responsible for this finding, a relation between the amount of processing resources and the speed of processing has to be presupposed. Caplan and Hildebrandt (1988) acknowledge this mutual relation by stating that a reduction in available work space is formally equivalent to an impairment in "the number of elementary computational operations that can be accomplished in a specified period of time (perhaps simultaneously) in a particular patient" (p. 275). The interdependence between processing resources and computational speed leads to a partial overlap between accounts specifying the impairment in terms of restrictions in computational resources, and accounts that are formulated in terms of temporal restrictions. I will return to this interdependence after the discussion of comprehension impairments in terms of changes in the temporal organization of language processing.

Temporal organization

Kolk and van Grunsven (1985) have recently infused new life into a tradition that assumes a relation between aphasic deficits and restrictions in the temporal organization of sentence processing (for suggestions in the same direction, see Linebarger et al., 1983b). Kolk and van Grunsven assume that all sentence elements, be they words, phrase structures, or whatever, need some time to become activated, following which they are subject to decay. During the construction of an interpretation from the sensory input, certain sentence elements have to be active simultaneously to allow the computation of the required sentence representations. This computational simultaneity is, for instance, presupposed between the verb and other nodes of the constituent structure so as to allow the assignment of thematic roles to the verb's internal arguments. Computational simultaneity might be lost if certain critical changes take place in the activation/decay functions of sentence elements, with disintegration of intermediate sentence representations as its consequence.

Kolk and van Grunsven (1985) distinguish two possible pathological changes in the activation and decay parameters of sentence elements. One is a faster-than-normal decay rate, resulting in a premature removal of sentence elements from the processor-internal working memory. The other is a slower-than-normal activation rate. They seem to claim that a slowing down of activation will reduce the number of elements which are simultaneously present in working memory, due to the increased time intervals between the moments that these elements are made available to working memory.[1] Thus faster-than-normal decay and slower-than-normal activation both lead to the same problem: disintegration of the representation before it has been adequately computed.[2]

The authors do not explicitly address the question whether pathological changes in the activation/decay function apply equally to all types of sentence elements (lexical items, phrase structures, etc.), or selectively to specific sentence elements. Let us therefore assume that they opt for the most general possibility: equal change for all elements. How compatible are these proposals with the data in the previous chapters?

The results discussed in chapter 3, especially the absence of a priming effect at the long ISI, is compatible with the idea of faster-than-normal decay for lexical items. The data reported in chapters 4 and 5, however, are difficult to account for in terms of an increased decay rate. First of all, in the long ISI-version of both series of experiments lexical activation for the context-biased meaning of the ambiguous words was still fully present in the Broca's aphasics. A fast decay of lexical-semantic information is incompatible with the pattern of facilitation that was obtained for target words in the biasing context at the 750 msec interval between sentence and target.

The later-than-normal selection of the biased reading of ambiguous words in both sentence context experiments (chapters 4 and 5) thus cannot be attributed to a faster decay of lexical information. By way of rebuttal, one could argue that in these cases a faster-than-normal decay of other sentence elements (e.g., phrase structures) has led to a premature disintegration of the context representation. The consequence would be that selection of either reading of ambiguous words on the basis of contextual information is less efficient than in the unimpaired language processor. However, on this account it remains completely unclear why contextual selection has been completed at the long, but not at the short ISI. Premature disintegration would affect contextual selection either at both ISIs or especially at the long ISI. If we take the data from the three studies together, the conclusion must be that they are not easily captured by an interpretation in terms of a faster-than-normal decay.

The same can be said for an interpretation in terms of a slower-than-normal activation of sentence elements. A decrease in the activation rate of lexical items does not explain why the strongest priming effects in a word context were obtained at the shortest ISI (chapter 3). It also cannot easily account for the obtained asymmetry in the selection of the noun and the verb reading of noun-verb ambiguities (chapter 5).

In conclusion, an overall change in the activation/decay rate of sentence elements cannot explain the complex pattern of results for the Broca's aphasics that emerged from the previous chapters. Possibly an account in terms of a selective change in the activation/decay rate for specific sentence elements might do better.

Recently, Friederici has outlined her views on the nature of the comprehension deficit in Broca's aphasics in terms of the temporal organization of sentence processing (Friederici, 1988a; Friederici & Kilborn, 1989). Friederici argues that the selectively slowed access to closed class elements results in a temporal mismatch in the availability of lexical-semantic and structural information. Structural information associated with closed class items in the lexicon plays a crucial role in the computation of the syntactic relations between the open class items in the sentence. Due to the delay in the access of closed class elements, their structural information is not available at the appropriate moments in time to allow the unhampered structural assignment of open class items. The parser thus is not able to keep pace with the incoming non-structural information, which prevents parsing operations to be executed with normal efficiency. Under this account it is not so much slowed processing per se that leads to the comprehension impairment, but rather a loss in the temporal fine-tuning of different processing components.

With respect to the Broca's aphasics, the reported data indicate that indeed processing of syntactic information encoded in inflectional endings seems to be impaired. The absence of stable priming effects for the noun-verb ambiguities (chapter 3), and the later-than-normal selection of the morphologically complex noun-reading in a syntactic context (chapter 5) are not incompatible with the hypothesized slower-than-normal access to closed class information. However, Friederici's account cannot explain the overall reduction in priming effects with increasing intervals between primes and targets (chapter 3). It is also difficult to attribute the delay in the contextual selection of ambiguous words on the basis of sentential-semantic context information (chapter 4), to a temporal mismatch between lexical-semantic and structural information. Structural information certainly did not play a direct role in the selection of lexical-semantic information in the experiments of chapter 4, since structural information did not constrain either of the two readings in any way. Thus, although the data do not exclude a specific impairment in the processing of structural information associated with closed class items in the lexicon, additional processing impairments must be assumed to account for the full set of data.

None of the current proposals on pathological changes in the temporal organization of processes involved in language comprehension can explain the combination of data without the help of additional ad hoc assumptions. Nevertheless, by tracking the time course of lexical-semantic activation in different kinds of context, I have shown that temporal aspects of language processing are affected in aphasic patients with a comprehension deficit. To explain the experimentally established facts I am thus forced to tell my own tentative story about the underlying impairment.

What is the functional locus of the comprehension deficits?

In mapping the sensory input onto a message representation, multiple lexical items are accessed, the item that best matches both input signal and context is selected, and the selected lexical information is integrated with the context representation which has been built up on the basis of the previously processed words. These three aspects of lexical processing are usually referred to as access, selection and integration (cf. Zwitserlood, 1989).

In all studies discussed in the previous chapters, ambiguous words were used to track the time course of lexical activation. For these words, meaning selection can only be based on contextual information. The meaning that can be integrated with the preceding context is selected. In this case, selection is a by-product of lexical integration. The locus of the delay in contextual selection (chapters 4 and 5) is therefore either at the level of lexical access or at the level of lexical integration. In the former case the semantic and structural information associated with lexical items is made available in a slower-than-normal rate. In the latter case the integration of lexical information is slower-than-normal. I will defend the latter option.

In my account I assume a temporal mismatch between lexical access and lexical integration. However, this mismatch does not arise as a consequence of a decrease in activation rate for lexical information, but is caused by an inability to integrate the lexical information within the context representation at the appropriate moment in time. How come? The proposed answer is: due to a reduction in computational resources.

The amount of processing resources determines the number of computational operations that can be accomplished per time unit. To illustrate this, one can use the metaphor of the internal computer clock. In general, the speed of processing increases with a higher clock rate. Conversely, decreasing the clock rate reduces the computational power of the system. A slower clock rate will affect complex computational operations more severely than relatively simple ones (the complexity effect).

Lexical access and lexical integration differ in the amount of computational resources that they require. Lexical access engages computational resources to retrieve lexical information that is stored in memory. The integration of this information into a higher-level representation requires the matching of the accessed lexical information against aspects of the context representation. Computational resources are invested in retaining the context representation and in the process of integrating the lexical information into this higher-level representation.

It is a reasonable assumption that lexical integration needs more computational resources than lexical access. Limitations in the amount of computational resources will therefore more severely affect lexical integration. As a result, the temporal coordination between lexical access and lexical integration is disturbed. Lexical integration is shifted in time relative to lexical access.

Under this hypothesis, pathological changes in the temporal organization of processes involved in language comprehension are intimately linked to a reduction in the computational resources available to the language processor. Empirical support for this hypothesis is mainly derived from the data of the Broca's aphasics. I will first discuss the supportive evidence for these patients. Then, I will evaluate whether the comprehension deficits of Wernicke's aphasics can be accounted for in a similar way.

In chapters 4 and 5 I have argued that a slowing down of lexical integration can explain the delayed selection of the contextually appropriate meaning of ambiguous words in Broca's aphasics. If this slowing down is caused, as hypothesized, by a restriction in computational resources, then the seeming contradiction between the priming effects in a word context ('faster decay'; chapter 3) and the results of both sentence context studies ('slowed activation'; chapters 4 and 5) can be resolved. What might seem to be faster decay and slowed activation of lexical information is in fact the result of slower-than-normal integration of contextual and lexical information.

On this account the loss of associative/semantic priming effects in a word context obtained at the longest ISI (chapter 3), is attributed to a failure of a different priming mechanism than automatic activation spreading. One of the processes involved in non-automatic priming effects can be referred to as meaning integration (cf. De Groot, 1990). In contrast to automatic spread of activation, the process of meaning integration is usually assumed to require allocation of processing resources and to be especially effective at longer intervals between primes and targets. A limitation in the amount of computational resources thus selectively affects meaning integration. This explains the absence of priming effects at relatively long intervals between primes and targets.

Additional, but indirect evidence in support of this hypothesis can be gained from the overall reaction times in the different experiments. Compared to younger and elderly control subjects, the Broca's aphasics were the only subjects who consistently showed longer overall reaction times at the short ISI compared to the long ISI. The only difference between short and long ISI versions was the amount of information to be processed per time unit, with a higher processing load at the shorter ISI. Friederici and Kilborn (1989) reported similar findings in a cross-modal priming study. In contrast to the normal control subjects, for the Broca's aphasics they obtained longer latencies to the visual targets when preceded by an auditory sentence context than when presented in isolation. Moreover, their aphasic patients, in contrast to their normal control subjects, showed longer latencies at the short ISI (0 msec) compared to the long ISI (200 msec) between context and target. This general trend in a number of different on-line studies suggests a rather nonspecific increase in response latencies if the amount of linguistic information to be processed within a certain time frame increases. The hypothesized reduction in the amount of computational resources is a rather natural explanation for this effect.

If we look at the data in each of the studies separately, then a number of alternative explanations remain. In trying to relate the data from the different studies to each other, however, the number of viable accounts is more constrained. I have suggested one hypothesis for the processing impairment involved in the comprehension deficits of Broca's aphasics. In my account I assume a relative delay in the time course of lexical integration due to a reduction in the amount of processor-internal computational resources. This account seems to be the one that is most compatible with the overall pattern of data reported in the previous chapters, but also with the often reported sentence complexity effect. In addition, it can easily handle the variability between patients (degree of severity). The degree of severity of the comprehension deficit is assumed to be related to the severity of the limitations in the amount of resources available to the comprehension system. The size of the reduction in computational resources can vary from patient to patient.

Does this account also explain the results for the Wernicke's aphasics? These patients showed the same pattern of performance in the word priming study as the Broca's aphasics (chapter 3). However, their performance in the study testing the effect of a sentential-semantic context on the resolution of lexical ambiguity was different from that of the Broca's aphasics. No reliable context effects were obtained. This suggests that the integration of lexical information into a higher-level message representation was totally unsuccessful. Swinney et al. (1989) also failed to find any indication of a contextual effect on the process of ambiguity resolution in Wernicke's aphasics. Although they only measured the effect of a sentence context at an ISI of 0 msec between the auditory context and the visual target, the pattern of results they reported for their normal control subjects suggested the emergence of a context effect.

By now a number of studies has shown that access to lexical-semantic information does occur in Wernicke patients. Lexical integration, however, seems to be severely disrupted. The locus of the comprehension deficit in Wernicke's aphasics is hypothesized to be at the post-lexical level of integrating currently accessed lexical information with information that has been previously accessed. Whether the impairment in these patients should be attributed to a limitation in processing resources remains to be seen. If this is the case, then the limitation would be much more severe than in the average Broca's aphasic. Given the restricted number of Wernicke's aphasics that has been tested, as well as the small number of the sentence context experiments they were tested on (chapter 4), no firm statements can be made concerning the nature of the underlying comprehension deficit in Wernicke's aphasia.

What are the implications for models of language processing?

The study of aphasic deficits does not necessarily derive its legitimization from the relevance it has for theories of unimpaired language processing. Nevertheless, the motivation behind much of the research in neurolinguistics and aphasiology is that the "experiments of nature" may contribute to our knowledge about the intact language processing system and its implementation in the brain. One possible question is therefore what the reported patient data imply for models of normal language comprehension.

It would be highly premature to use the data of this thesis to make bold assertions about the amount of resources required for unimpaired language processing, or to make claims about the temporal bandwidth that is critical for different processing components. However, the changes in the time course of lexical integration processes as they were observed in the suboptimal processing system of aphasic patients, illustrate the importance of questions related to computational resources and temporal organization. Some of these questions are largely ignored in psycholinguistics, but they are nevertheless relevant for the construction of a realistic model of the intact listener. I will mention three of them. First, what is the nature of the processing resources that are involved in unimpaired language comprehension, and what amount of resources is required? Second, what is the tolerance of the system for temporal mismatches in the delivery of different kinds of information (e.g., lexical-semantic, structural, etc.)? Third, what are the back-up mechanisms that can be engaged if a first-pass analysis fails? It is to be hoped that further on-line studies on aphasic impairments will contribute to answering these questions.

Final conclusion

Reducing the problem space does not automatically lead to the solution of the problem that one started out with. This applies equally to the problem addressed in this thesis, which can be formulated as follows: what is the nature of the impairment(s) we have to postulate in our processing model of the listener to account for the comprehension deficits in aphasic patients. Although my hope is that the research I have reported contributes to a further reduction of the problem space, I would not want to claim that I have solved the problem that motivated my research efforts. This series of concluding remarks thus inevitably leads to the most trivial of all: it is still a long way to Tipperary.

NOTES

Chapter 1

1. More recent on-line methods no longer require subjects to produce an overt response. Recordings of eye movements during reading, of pupil dilation during speaking, or of event-related brain potentials (ERPs) during listening or reading can be obtained in the absence of a secondary task.

2. Originally Kolk described adaptation theory as a theory about the patient's reaction to the impairment and not as a theory of the impairment itself (Kolk & van Grunsven, 1985). However, in a more recent publication adaptation theory is presented as "a new theory of grammatical impairment in aphasia" (Kolk, 1987; p. 377). Thus, it is not completely clear whether or not Kolk wants to subsume his ideas about the nature of aphasic deficits under the heading of adaptation theory. In my view it would be unfortunate to do so, since there is no transparent causal relation between the nature of the impairment and the adaptive behavior shown in response to the impairment. Although the claim concerning telegraphic style as a form of adaptation is inconsistent with certain views on the underlying impairment (e.g., a complete loss of syntax), it nevertheless leaves room for a whole range of possible deficits (e.g., different types of resource limitations). The adaptive value of a specific form of adaptation can be the same for different underlying deficits. Thus, there is at best a loose connection between the nature of the impairment and the form of adaptation. If we reserve the predicate 'theory' for an internally consistent set of interrelated propositions which enable the derivation of unambiguous and testable consequences, then adaptation theory should refer to the language behavior of aphasic patients, but not to their underlying deficits in the functional architecture of the language processing system. I will use the term adaptation theory in this strict sense.

3. Of course, in theory one can increase the number of items to obtain a more reliable database in a single-case study. However, very often this will not work for practical reasons. The constraints on the construction of the materials in many psycholinguistic experiments severely limit the possibility for the required increase in the number of items. Moreover, the availability of the patient both in terms of time and motivation also restricts the possibility for the concomitant increase in the duration of the test sessions.

4. All the information collected for this set of Dutch homonyms will be made available upon request.

Chapter 2

1. Milberg et al.'s construction of the unrelated triplets differed in one respect from those of Schvaneveldt et al. The latter authors had no triplets consisting solely of unambiguous words. Because one does not know the contribution of the ambiguity

itself, it might have been better to also construct the unrelated triplets (the baseline) in the same way as Schvaneveldt et al. did: three unrelated words of which the second is ambiguous.

2. The effect for ambiguity type is not very revealing. It is possibly caused by factors that are not of immediate interest here, such as differences in the length of the target words within the types. The absence of a significant interaction with priming condition, however, is revealing. It shows that there is no special contribution of the word-class difference to the effects of priming conditions.

Chapter 3

1. A possible argument against this account of the diverging pattern of results in studies using different tasks, is to argue that priming studies using associatively related words do not tap into the 'real' lexical semantics. However, this argument will not get us very far, for two reasons. First, there is evidence that the mechanisms underlying associative and semantic priming are the same (de Groot, 1990). Second, fluent aphasics are also shown to be sensitive to purely semantic (non-associative) priming (Friedman, Glosser, & Diamond, 1988).

2. According to Becker (1980, 1985) expectancy alone can account for priming. However, one of the major problems of this theory is that it cannot (easily) explain the effects of SOA on priming.

3. Although only the analyses on the medians per condition are reported, analyses were always also done on the means per condition. Although the F-values for the main effects were in general larger for the analyses of variance on the means, the overall patterns of significance were almost the same. The interpretation of the results is, therefore, in no way dependent on the choice to report analyses on the medians. For repeated measures designs the underlying assumption is that the covariance matrix is homogeneous for the levels of the factor of interest, and that this matrix shows compound symmetry (Winer, 1971). If it cannot be made sure that the data fit these requirements, sometimes the adaptation of the degrees of freedom according to the test procedure outlined by Greenhouse and Geisser is advocated. The Greenhouse-Geisser procedure, however, results in a conservative test that errs in the direction of not rejecting the null hypothesis when it is false. Winer (1971) mentions Monte Carlo studies indicating "that the usual tests suggested by the analysis of variance tend to give results closer to the nominal significance levels than do results under the Greenhouse-Geisser conservative approach, provided the degree of heterogeneity of the covariances is relatively moderate" (p. 524). The post-hoc comparisons on the results of the experiments reported here were based on the Newman-Keuls procedure. The Newman-Keuls procedure is, however, also on the conservative side compared to other tests of individual differences between conditions (e.g., the F-statistic used in individual comparisons, or the Duncan test). Therefore, to avoid a relatively high probability of type 2 errors, I decided not to apply the Greenhouse-Geisser test procedure.

4. The results of the anomic patient were not entered into the analyses of the results

for the Broca's and Wernicke's aphasics. His results, however, were very much in agreement with those of the other patients. His overall median RTs per priming condition were as follows (in msec): 703 (concordant), 813 (discordant), 797 (neutral), 829 (unrelated).

5. Given the limited size of especially the group of Wernicke patients (five patients in experiment 1, and four in the remaining experiments), in a first analysis these patients were pooled with the Broca's aphasics, provided that no significant interaction between Patient Group and Priming Condition was obtained. The absence of this interaction indicates that there is no statistical reason to analyse both patient groups separately with respect to the effects of Priming Condition. The analysis of the pooled group data was primarily done to establish whether the overall priming effects reached significance and, as such, to determine the general sensitivity of the patients for the semantic context information contained by the primes. More fine-grained interpretations with respect to a possibly differential sensitivity to noun-noun and noun-verb ambiguities were based on separate analyses for both patient groups.

6. Homogeneity of variance was tested using the F-max statistic (Winer, 1971). For both types of ambiguity the variances for the items in the neutral condition were compared to the largest of the other conditions to obtain an F-ratio. For the two types of ambiguity this resulted in an F-ratio smaller than one. The variance of the neutral condition did not deviate from the variances of the other conditions. Variances of the other conditions also did not show a deviation from homogeneity. The study by Holley-Wilcox and Blank (1980) showed that in the absence of a biasing context, both meanings of an ambiguous word are accessed. The results of this study are consistent with their results.

7. In the case of the noun-verb ambiguities, a more direct contribution of form class priming cannot be totally excluded. In the concordant condition for 7 out of the 16 noun-verb items the grammatical form class of the first prime matched with that of the target-related reading of the ambiguity. However, in the discordant condition the first prime shared in only one case its grammatical form class with the target-related reading. If form class directly biases the interpretation of the ambiguous words, the concordant condition has a slight advantage over the discordant condition. Empirical evidence that subjects can be brought to use form class information to bias their interpretation of noun-verb ambiguities has been obtained in a study by Roydes and Osgood (1972).

8. The size of the difference is also rather large in comparison with the overall difference in latency between the groups of normal control subjects in both studies. Although no information on the mean age of the normal controls is given in the Milberg et al. study, they were overall only 45 msec slower than the elderly subjects, and 121 msec slower than the young subjects in my studies (see chapter 2).

9. A comparison between the results of the eleven patients who participated both in Experiment 1 and in Experiment 2 suggests that priming effects were even stronger at the short ISI of 100 msec. This suggestion is based on the larger

overall F-values and the larger mean squares for the priming conditions (MSpc) obtained with an ISI of 100 msec. Comparing the results at the ISI of 100 msec and 500 msec led to the following outcomes for the group of eleven aphasic patients: ISI=100 msec: $F(3,30)=10.86$, MSpc=24118; ISI=500 msec: $F(3,30)=3.78$, MSpc=12479. For the group of Broca patients, who are claimed to have an impairment in automatic lexical-semantic processing, the following results were obtained: ISI=100 msec: $F(3,18)=5.86$, MSpc=15523; ISI=500 msec: $F(3,18)=2.54$, MSpc=5748. Although one has to be very cautious in interpreting differences in F-ratios, nevertheless, the conclusion seems warranted that the priming effects are certainly not weakened by reducing the ISI, and thereby increasing the contribution of ASA.

10. In prototypical implicit memory experiments, subjects are presented with stimuli such as words, line drawings, and faces. In the later test phase which may follow the first presentation with an interval that can vary from seconds to months, the subjects are mostly given reduced perceptual information about the previously presented stimuli. They are asked to identify the stimuli. If, as a consequence of the first presentation, the probability of identification increases or the identification latency decreases, priming is said to have been demonstrated (Tulving & Schacter, 1990). The present study repeated target words that were not reduced in their perceptual information, but identical to the first presentation. This, however, is not a principled difference from the standard approach in investigating implicit memory.

11. Recent studies have shown that accessing morphologically complex words does not require pre-lexical decomposition into stems and affixes (Emmorey, 1989; Schreuder, Grendel, Poulisse, Roelofs, & van de Voort, 1990; Schriefers, Zwitserlood, & Roelofs, 1990; Tyler, Marslen-Wilson, Rentoul, & Hanney, 1988). This holds even if the word consists of a stem and an inflectional suffix (Schreuder et al., 1990). The results of these studies, however, do not imply that the accessed lexical representations do not have morphological structure. Recent studies suggest that lexical representations themselves might be morphologically decomposed (Bergman, 1988; Caramazza, Laudanna, & Romani, 1988; Schriefers et al., 1990). The evidence for morphologically decomposed lexical representations is more unequivocal for highly inflected languages such as Italian, than for languages with a relatively simple inflectional system such as Dutch and English. For Dutch, some studies did not find empirical support for morphologically decomposed lexical representations (Jarvella, Job, Sandstrom, & Schreuder, 1987; Schreuder et al., 1990). However, the results in a few other studies do give support to the decomposed representation view of Dutch words (Bergman, 1988; Schriefers et al., 1990).

12. The absence of a differential effect for verb-related targets and noun-related targets also excludes an explanation in terms of a citation-form preference. In a recent syllable monitoring experiment in Dutch, some evidence has been found for a special status of citation forms during lexical access (Zwitserlood, Schriefers, Lahiri, & van Donselaar, 1988). Given that in Dutch the verb-infinitive is the citation form of verbs, while the noun-plural is not the citation form of nouns, a citation-form preference should likewise have led to an interaction between

Form-Class Relatedness and Priming Condition. The absence of such an interaction is, therefore, also evidence against an account in terms of a citation-form preference.

Chapter 4

1. In addition to context, the relative frequencies of occurrence of the different readings of an ambiguous word also play a role in the selection process (see further on in the text).

2. The underlying assumption in this type of research on the resolution of lexical ambiguity is that the results are representative of contextual effects on lexical-semantic processing in general. Indeterminacy of meaning is a pervasive phenomenon in language. Most words have more or less different senses according to the context in which they appear. In the absence of a well-defined theory of the semantics of natural languages, it is problematic to draw a clear formal boundary between ambiguous words with multiple meanings and unambiguous words with multiple senses (cf. Lyons, 1977; Johnson-Laird, 1983). Words with multiple meanings are for experimental purposes the more clear-cut cases. This has led most experimenters to study the processing of words with multiple meanings instead of those with multiple senses, assuming that the differences between words with multiple meanings and words with multiple senses is more a matter of expediency than of principle (cf. Simpson, 1984).

3. Next to measuring priming effects, other studies have tried to tap the processing of lexical ambiguities by measuring its consequences for processing load in tasks such as phoneme monitoring (e.g., Foss & Jenkins, 1973; Cairns & Kamerman, 1975), or by measuring the time it takes a subject to detect the ambiguity (e.g., Forster & Bednall, 1976; Hogaboam & Perfetti, 1975; Neill, Hilliard, & Cooper, 1988), or even by measuring its effect on heart rate (Mohanty, 1983). These tasks and measures, however, seem less suited for determining at what phase of lexical processing context has its influence, and are not at all suited for tracking the time course of meaning selection. For a review of these tasks, see Simpson (1984).

4. Seidenberg et al. (1982) interpreted this result as indicating selective access in a lexical context. In the previous chapter we have seen that the results of selective activation in lexical contexts can also be attributed to a very rapid selection process. In this case, priming does not completely prevent access of the non-biased meaning, but the selection of the contextually appropriate meaning is completed much faster than in a sentential-semantic context.

5. In this example there is also a strong semantic relation between a word in the context (*ship*) and the ambiguity (*port*). According to Tabossi (1988) this was the only item in the set of materials that contained such a semantic and/or associative relation between words in the context and the ambiguous noun.

6. Marta Kutas' counterargument (personal communication) against this objection is that today's psycholinguistic experimentation has not seen a single task that can

be safely claimed to measure nothing but lexical access. This seems a fair statement. However, in the imperfect world we live in relatively much is known about tasks that are part and parcel of current psycholinguistics, such as lexical decision and naming. The possibilities, problems, and complexities of these tasks in measuring lexical access have been the subject of a large amount of experimental work (e.g., Balota & Chumbley, 1984; de Groot, 1984; de Groot, Thomassen, & Hudson, 1986; Neely, 1977, 1990; Seidenberg, Waters, Sanders, & Langer, 1984). As a result, at this moment we know more about what we are allowed to conclude from latency data obtained with lexical decision or naming tasks than from the ERP-wave time-locked to the processing of lexical ambiguities. Actually, mainly due to the work by Kutas and her colleagues (e.g., Kutas & Hillyard, 1980a, 1980b, 1980c, 1983, 1984, 1988), ERP-research has only in the last decade been proven to be a promising new track to pursue in psycholinguistics. Given our current, limited knowledge about the way in which different phases of lexical processing are reflected in specific ERP-components, the results of the Van Petten and Kutas study are open to a number of different interpretations.

7. One can argue that in addition to the two normal control groups, one or even two additional control groups should be tested: one control group consisting of patients with a right-hemisphere lesion, and another consisting of patients with a left-hemisphere lesion, but without aphasia. It cannot be denied that this would further increase the reliability of the testing procedures. However, practical constraints simply made it impossible in the case of the present studies. Moreover, urgent reasons to expect that the interpretation of the results for the aphasic patients would have been different if the experimental tests were also done with these additional control groups, are lacking. First, experimental research bearing on the temporal aspects of speech processing in aphasia has not found any evidence for a deficit in brain-damaged patients without aphasia (Efron, 1963; Tallal & Newcombe, 1978). Second, the aim of my research is to interpret the pattern of performance for the aphasic patients in terms of a model of the listener. This model is established on the basis of research with neurologically unimpaired subjects. The results of the control group should confirm the adequacy of the interpretative framework. Whether other subject groups, such as alcoholics, schizophrenics, hospitalized subjects without brain-damage, etc. show a normal pattern of performance in tests of language processing remains to be seen. A priori, there is no reason to assume their pattern to be abnormal. But even if it would turn out to be abnormal, it is not immediately clear what the consequences are for the interpretation of the data obtained for the aphasic patients. For these two reasons, testing additional control groups with brain-damaged patients would almost certainly have been a waste of time.

8. The probability values are solely based on the meanings of the ambiguous nouns that were used in this study. If subjects gave responses that could not be classified as related to one of both meaning alternatives, these responses were eliminated when computing the probabilities. In this way the sum of probabilities for both meanings was 1.00 in all cases.

9. A more or less literal English translation of the examples of the actual Dutch material, is given below.

Context Condition	Sentence	Target Word
	Target Type: Dominant	
Concordant:	*The cleaning lady removed the spilled ASH.*	*SMOKE*
Discordant:	*The steelworker welded the broken SHAFT.*	*SMOKE*
Unrelated:	*The nature lover saw a rare BEE.*	*SMOKE*
	Target Type: Subordinate	
Concordant:	*The winner finally played his ACE.*	*CARD*
Discordant:	*The boy finally attached his BAIT.*	*CARD*
Unrelated:	*The customer finally bought the BED.*	*CARD*

10. The remaining percentage of the responses did not relate to either of the meaning alternatives that were used in this study.

11. Analyses were done on the medians for reasons given in the previous chapter. However, a checking procedure was followed in that the same analyses were also done on the means per condition. These analyses confirmed the results of analyses on the medians per condition in all cases.

12. In the planned comparisons, the error term is based on the data from the cells which are used in the computation of the means being compared. According to Winer (1971), this error term is to be preferred over the pooled error term based on the data from all cells entering the overall ANOVA, especially if the number of degrees of freedom is sufficiently large for the unpooled error term. Although the choice of the most appropriate error term is not a matter of agreement among statisticians, especially for repeated measures designs the use of separate error terms in testing pairwise comparisons is strongly recommended by a number of authors (cf. Boik, 1981; see also Westermann & Hager, 1983a, 1983b).

13. Another way to test whether repetitions of ambiguous words and target words had led to special processing strategies, is by conducting analyses which include presentation version as a separate factor. Interactions of Presentation Version with Target Type or with Congruency would indicate the operation of such strategies. Analyses including Presentation Version as a separate factor did not yield significant interactions of Presentation Version with the other variables. This further supports the conclusion that repetition of targets and ambiguous words did not change the pattern of results for the relevant variables. Other studies on ambiguity resolution also showed that the pattern of results did not change as a

consequence of repeating the material (Seidenberg et al., 1982; Tanenhaus et al., 1979).

Chapter 5

1. Phonological phrases are intermediate in size between words and syntactic phrases. Phonological phrases always contain, and usually end on the head of a syntactic phrase. Moreover, each phonological phrase has one major stress, which normally falls on the head (see also Tyler & Warren, 1987). Tyler (1989) defines a phonological phrase as a unit of local structure that has prosodic, semantic and syntactic coherence. However, this definition is incorrect because phonological phrases are not syntactic or semantic units. That they can and often do overlap with syntactic and semantic units, does not mean that their structuring is guided by syntactic and semantic principles. To defend the choice of phonological phrases as the major form of local structure because they consist of "groups of adjacent words which form syntactic, prosodic, and semantic units" (Tyler, 1989; p. 337) is thus an overstatement of their linguistic information value.

2. Other evidence for this conclusion was obtained from D.E.'s sensitivity to subcategorisation violations. However, given the materials used, there is some debate as to whether this effect is really syntactic or due to the built-in semantic anomalies, as has been argued by Caplan (see Tyler, 1989).

3. Noun-verb ambiguities are chosen for two reasons. First, psycholinguistic research on the resolution of lexical ambiguities has restricted itself to noun-noun and noun-verb ambiguities. Second, to find a sufficient number of lexical ambiguities in Dutch with both meanings belonging to different form classes, one is forced to choose the items from among noun-verb ambiguities.

4. A more or less literal English translation of the Dutch examples is given below.

   N-bias: *The girl has problems with the majority of TONES.*
   Control: *The girl has problems with the majority of SUMS.*

   V-bias: *The man did not know yet what he was going to SHOW.*
   Control: *The man did not know yet what he was going to COOK.*

5. A more or less literal English translation of the Dutch examples is given below. Inspection of the items after the experiments had been finished, revealed that in one of the noun-related items the discordant context biased a nominalization of the verb. This particular context sentence thus did not fit the criterion that a noun should be excluded as the sentence-final word. Because the results showed that this item did not behave differently from the other noun-related items, I decided not to exclude it from the analyses.

Context Condition	Sentence	Target Word
	Target Type: Noun-related	
Concordant:	*In total he fixed as much as twelve HANDLES.*	*DOOR*
Control:	*In total he fixed as much as twelve BUTTONS.*	*DOOR*
Discordant:	*One expects on this to be able to TOAST.*	*DOOR*
Control:	*One expects on this to be able to GUESS.*	*DOOR*
	Target Type: Verb-related	
Concordant:	*In hurry he had it forgotten to SANDPAPER.*	*SHARPEN*
Control:	*In hurry he had it forgotten to WASH.*	*SHARPEN*
Discordant:	*Everywhere you see here today big BARNS.*	*SHARPEN*
Control:	*Everywhere you see here today big SLOGANS.*	*SHARPEN*

6. The remaining responses could not be classified as related to either meaning of the noun-verb ambiguities.

7. In the pairwise comparisons, the error term is based on the data from only those cells which are used in the estimation of the means being compared. The reasons for preferring this error term over the pooled error term are given in the previous chapter.

8. The reported difference in the meaning frequencies of both readings was based on the lemma counts given by Uit den Boogaart (1975), and not on the frequencies of the specific word forms as they were used in the experiment. However, the frequencies of the word forms showed the same picture as the lemma frequencies. That is, the word forms of the ambiguities in the set of verb-related items had a higher mean frequency for the noun reading (18.4) than for the verb reading (10.6).

9. A possible explanation for the asymmetry in the selection of noun and verb readings is related to the way inflected word forms might be represented in the mental lexicon. In proposals along the lines of the satellite-entries hypothesis of Lukatela et al. (Feldman & Fowler, 1987; Günther, 1988, 1989; Lukatela, Gligorijević, Kostić, & Turvey, 1980), entries in the mental lexicon are assumed to be composed of a nucleus which contains the base form, and satellites containing all other forms of the paradigm. In addition, lexical access via the nucleus is thought to be faster than via a satellite. In his version of this proposal Günther (1989) argues that in languages such as German and Dutch the citation

form makes up the nucleus of the lexical entries for nouns and verbs. The nucleus for Dutch nouns thus is the nominative singular, for Dutch verbs it is the infinitive. Empirical evidence for a special status of citation forms in lexical access of Dutch words can be derived from a study by Zwitserlood, Schriefers, Lahiri, and van Donselaar (1988). In a syllable monitoring experiment these authors found shorter latencies when the target matched the stem of the spoken carrier word, provided that the target constituted a citation form.

Taking this particular constellation of lexical representations and processing assumptions for granted, the following explanation for the results of the Broca patients can be derived. Because in this study with 32 noun-verb ambiguities most of the verb forms had an infinitival interpretation and most of the noun forms a plural one, the verb reading of most of the homonyms has a nucleus status, while their noun reading has in most cases the status of a satellite. This implies that normally the verb reading is accessed faster than the noun reading. If in the Broca patients lexical access is slower-than-normal, the verb reading might have become available within the time frame imposed by the short ISI of 100 msec, while at the same time the noun reading has not yet been fully retrieved. As a consequence, at the short ISI contextual selection has taken place for the verb reading, but not for the noun reading.
This explanation is, however, unlikely for the following reasons. The results of Experiment 1b showed that in the Broca's aphasics as in the normal controls facilitation emerged for both noun-related and verb-related targets in the concordant context. This implies that lexical access has taken place not only for the verb reading but also for the noun reading of the homonyms. Such a pattern of results can only arise under the additional assumption that the moment in time at which the activational status of both readings was probed in Experiment 1b coincided with the completion of lexical access and the beginning of contextual selection (i.e. integration) for the noun interpretation of the homonyms. Such an explanation cannot be excluded, but it would require additional evidence that the measurement situation happened to realize this particular state of affairs.

In addition, there is no clear empirical evidence that the specific organisation of lexical entries and their processing consequences, which are presupposed in this account, hold for the mental lexicon of Dutch language users (see also chapter 3). Together, therefore, the set of additional assumptions necessary to interpret the results of the Broca's aphasics in this particular way overstresses, it seems to me, the general underdetermination of the theory by the data.

10. Overall analyses were also done on the means per condition. In this case, latencies in the discordant context were 7 msec shorter for the noun-related targets and 8 msec shorter for the verb-related targets relative to the baseline conditions. Planned comparisons showed that these differences were not significant (respectively, $F(1,47)=2.53$, $p=.11$; $F(1,47)=2.22$, $p=.14$). This further indicates that the relatively small amount of facilitation obtained in the overall analyses on the subjects' medians per condition, should be interpreted with extreme caution. The first-block analyses and the overall analyses on the subjects' means per condition suggest that no reliable facilitation occurs for targets in a discordant context.

11. The patient with the deviant pattern of results had a much higher standard

deviation than the other patients. This was mainly due to the problems he had in controlling his fingers while pressing one or other of the buttons on the keyboard. When the data of this patient were excluded from the analyses, the pattern of results for both ISIs did not change, except for the one comparison in Experiment 2b. Table 12 gives the results of the Broca's aphasics when the latencies of this patient are removed from the data. The results of planned comparisons after exclusion of this patient are as follows for the data of experiment 1b: the 83 msec facilitation for the noun-related and the 40 msec facilitation for the verb-related targets in the concordant context are marginally significant ($F(1,6)=5.41$, $p=.059$; $F(1,6)=4.32$, $p=.083$ respectively). No facilitation was obtained for the noun-related targets in the discordant context ($F<1$). However, a significant facilitation of 64 msec emerged for the verb-related targets in the discordant context ($F(1,6)=10.96$, $p<.05$).

TABLE 12

Means of the median auditory lexical decision times as a function of Context Condition and Target Type (ISI=100 msec and ISI=750 msec), for the group of Broca's aphasics after removal of the deviant patient.

Target Type	Noun-related		Verb-related	
Context Condition	RT	d	RT	d
	ISI=100 msec			
Concordant	791	83	880	40
Concordant Control	874		920	
Discordant	869	−2	867	64
Discordant Control	867		931	
	ISI=750 msec			
Concordant	796	43	826	32
Concordant Control	839		858	
Discordant	800	16	864	18
Discordant Control	816		882	

Differences (d) are measured relative to the control conditions.

The individual patient data supported the overall group results. At the ISI of 100 msec, seven patients had shorter latencies for the noun-related targets in the concordant condition compared to the appropriate control condition, while only three patients had shorter latencies in the discordant condition compared to the discordant control condition. For the verb-related targets, six patients had shorter latencies in the concordant condition and seven in the discordant condition compared to their respective controls.

At the ISI of 750 msec, compared to the relevant control conditions seven patients had shorter latencies in the concordant condition for the noun-related targets, and eight patients had shorter latencies in the concordant condition for the verb-related targets. For both target types in the discordant condition four patients were faster and four patients were slower relative to the appropriate control conditions.

Chapter 6

1. The actual phrasing used by Kolk and van Grunsven (1985) does not make the underlying idea particularly clear. In their explication of a possible decrease in activation rate, they write that "if the activation of lexical or syntactic elements ... is slowed down, the result will again be premature decay of some elements (not necessarily the ones whose activation is slowed down) and disintegration will result. Note that although memory limitation (in particular its duration) is involved here, it is not postulated that memory itself is affected by brain damage. There is an activation delay, which, as the result of normal limitation in duration, takes the appearance of an actual memory deficit." (p. 372). It is not completely clear what is meant by memory duration. I take it to mean that with normal decay rates, the increased time interval between the activation of different sentence elements leads to a reduction in the number of elements that are active at the same time. This, however, only holds if the activation of different sentence elements is hierarchically ordered. If activation of different sentence elements (e.g., words) is mutually independent, the first will become available later than normal, but the remaining elements will be made available with the same time intervals as before.

2. To explain within-subject variation in language processing performance (e.g., in processing passive sentences at different moments in time), Kolk (1987) added the assumption of random variation in activation and decay rates. He suggests that "such variation could be due to autonomous biochemical changes in the brain." (p. 384). Kolk, moreover, argues that the temporal deficit hypothesis can handle the within-subject variation more easily than an account that specifies the impairment in terms of limitations in the processor-internal working memory. Again, the argumentation refers to alleged compatibility with principles derived from neuroscience, as is suggested by the following quote: "Perhaps it could also be maintained that buffer size varies from moment to moment, although such an assumption seems somewhat less plausible as the number of slots appears to be a property of the hardware rather than an aspect of process." (p. 384). Both quotations are nice illustrations of the neurobiological fallacy which I have challenged in extenso elsewhere (Brown & Hagoort, 1989). To use

neuroanatomical or neurophysiological principles as one of the criteria to decide among different functional models of cognitive faculties or their impairments, presupposes a much more direct relation between the structure of the functional architecture and the structure of the brain than one is warranted to assume on the basis our current knowledge about the relation between brain and cognition (cf. Fodor, 1975; Mehler, Morton, & Jusczyk, 1984). Since we know very little about the correspondence relation between the functional architecture of the language system and its implementation in the brain, there is not the slightest reason to assume that the neurophysiological implementation of random fluctuation in buffer size might be less compatible with our knowledge of the brain than random fluctuation in functional activation or decay. Borrowing the words from neuroscience (e.g., activation) does not guarantee that they bring along their reference objects to cognitive science.

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APPENDIX 1

Experimental word target triplets used in the studies of chapters 2 and 3. For each target word the priming conditions are specified in the following order: *concordant, discordant, neutral, unrelated.*

Noun-Noun Ambiguities

(01) kopen - artikel - winkel
nieuws - artikel - winkel
menen - artikel - winkel
nieuws - menen - winkel

(02) tafel - bank - stoel
overval - bank - stoel
orde - bank - stoel
overval - orde - stoel

(03) razzia - inval - politie
gedachte - inval - politie
schuit - inval - politie
gedachte - schuit - politie

(04) mast - kiel - boot
feest - kiel - boot
gips - kiel - boot
feest - gips - boot

(05) journalist - pers - krant
sinaasappel - pers - krant
eigenschap - pers - krant
sinaasappel - eigenschap - krant

(06) geld - piek - gulden
kerst - piek - gulden
dorp - piek - gulden
kerst - dorp - gulden

(07) leraar - pupil - leerling
oog - pupil - leerling
keuken - pupil - leerling
oog - keuken - leerling

(08) begin - slot - einde
deur - slot - einde
gezag - slot - einde
deur - gezag - einde

(09) directie - staf - medewerker
sinterklaas - staf - medewerker
opening - staf - medewerker
sinterklaas - opening - medewerker

(10) water - ton - regen
loten - ton - regen
avond - ton - regen
loten - avond - regen

(11) zadel - tuig - paard
bende - tuig - paard
forum - tuig - paard
bende - forum - paard

(12) vleugel - veer - vogel
pont - veer - vogel
respect - veer - vogel
pont - respect - vogel

(13) pen - vel - papier
huid - vel - papier
lof - vel - papier
huid - lof - papier

(14) sneeuw - vorst - kou
koning - vorst - kou
staart - vorst - kou
koning - staart - kou

(15) tijd - slinger - klok
jarig - slinger - klok
heer - slinger - klok
jarig - heer - klok

(16) bier - kater - drank
poes - kater - drank
piano - kater - drank
poes - piano - drank

Noun-Verb Ambiguities

(17) kleding - pakken - kostuum
grijpen - pakken - kostuum
termijn - pakken - kostuum
grijpen - termijn - kostuum

(18) liefde - kussen - vrijen
laken - kussen - vrijen
bezoek - kussen - vrijen
laken - bezoek - vrijen

(19) zee - varen - schip
plant - varen - schip
rest - varen - schip
plant - rest - schip

(20) theater - rollen - toneel
stuiten - rollen - toneel
inwoner - rollen - toneel
stuiten - inwoner - toneel

(21) dapper - wagen - durven
garage - wagen - durven
eczeem - wagen - durven
garage - eczeem - durven

(22) schieten - pijlen - boog
meten - peilen - boog
trachten - pijlen - boog
meten - trachten - boog

(23) kuil - graven - gat
adel - graven - gat
lood - graven - gat
adel - lood - gat

(24) partij - kiezen - stemmen
gebit - kiezen - stemmen
jongen - kiezen - stemmen
gebit - jongen - stemmen

(25) soldaat - gebieden - bevel
landstreek - gebieden - bevel
fiets - gebieden - bevel
landstreek - fiets - bevel

(26) pruik - lokken - haren
verleiden - lokken - haren
grieven - lokken - haren
verleiden - grieven - haren

(27) priesters - missen - kerk
heimwee - missen - kerk
maaltijd - missen - kerk
heimwee - maaltijd - kerk

(28) enkels - polsen - horloge
vragen - polsen - horloge
recept - polsen - horloge
vragen - recept - horloge

(29) steden - wijken - buurten
vluchten - wijken - buurten
gevoel - wijken - buurten
vluchten - gevoel - buurten

(30) saai - balen - vervelen
stro - balen - vervelen
doof - balen - vervelen
stro - doof - vervelen

(31) inbraak - stelen - dief
pannen - stelen - dief
veiling - stelen - dief
pannen - veiling - dief

(32) riem - leren - schoen
studie - leren - schoen
biet - leren - schoen
studie - biet - schoen

APPENDIX 2

Individual subject data for subjects participating in Experiments 1, 2, and 3 of chapter 3. For each individual subject the rank ordering of the median RT's in the four priming conditions and the two ambiguity types is specified. In addition summary tables are presented which are based on these rank orders. Rank orders of individual patient data are only specified for the aphasic patients who participated in all four experiments of chapter 3. Abbreviations are as follows: *concordant condition* (c), *discordant condition* (d), *neutral condition* (n), *unrelated baseline condition* (u).

Normal Control Subjects (N=12), Noun-Noun Ambiguities

	ISI=100 msec	ISI=500 msec	ISI=1250 msec
(01)	c<n<u<d	c<d<n<u	c<u<n<d
(02)	c<n<u<d	d<c<n<u	c<d<u<n
(03)	d<c<u<n	n<d<u<c	c<d<n<u
(04)	c<n<u<d	c<d<n<u	c<d<n<u
(05)	d<n<c<u	c<n<d<u	c<n<d<u
(06)	n<c<d<u	c<d<n<u	c<d<n<u
(07)	c<d=n<u	c=d<u<n	n<u<d<c
(08)	c<n<u<d	d<c<n<u	c<d<n<u
(09)	c<d<n<u	c<n<d<u	c<n<d<u
(10)	d<c<n<u	d<n<c<u	n<d<c<u
(11)	n<d<c<u	d<c<u<n	c<n<d<u
(12)	n<c<d<u	n<d<c<u	c<d<u<n

Summary table of the rank ordering for RTs on triplets with noun-noun ambiguities. Mean ranking per Priming Condition.

Priming Condition	ISI=100	ISI=500	ISI=1250
Concordant	1.7	1.9	1.4
Discordant	2.6	1.8	2.5
Neutral	2.1	2.6	2.6
Unrelated	3.6	3.7	3.5
	c<n<d<u	d<c<n<u	c<d<n<u

Normal Control Subjects (N=12), Noun-Verb Ambiguities

	ISI=100 msec	ISI=500 msec	ISI=1250 msec
(01)	c<n<u<d	c<n<d<u	n<c<u<d
(02)	c<u<n<d	c<n<u<d	c<u<n<d
(03)	n<c<u<d	c<d<u<n	c<n<u<d
(04)	c<n<d<u	n<c<u<d	c<n<u<d
(05)	c<u<n<d	c<n<u<d	n<c<u<d
(06)	c<n<u<d	c<n<u<d	n<c<u<d
(07)	c<u<d<n	c<d<u<n	c<n<d<u
(08)	n<c<u<d	n<c<u<d	n<u<c<d
(09)	n<u<c<d	c<n<u<d	c<n<u<d
(10)	c<n<u<d	n<c<u<d	c<u<n<d
(11)	c<n<u<d	d<c<n<u	c<n<u<d
(12)	n<c<u<d	n<c<d<u	u<n<c<d

Summary table of the rank ordering for RTs on triplets with noun-verb ambiguities. Mean ranking per Priming Condition.

Priming Condition	ISI=100	ISI=500	ISI=1250
Concordant	1.4	1.4	1.6
Discordant	3.8	3.3	3.9
Neutral	2.0	2.1	1.8
Unrelated	2.8	3.3	2.7
	c<n<u<d	c<n<u=d	c<n<u<d

Aphasic Patients (N=11), Noun-Noun Ambiguities

	ISI=100 msec	ISI=500 msec	ISI=1250 msec
(01)	c<n<d<u	n<d<c<u	c<d<n<u
(02)	c<n<d<u	d<c<n<u	c<d<u<n
(03)	c<d<n<u	d<u<n<c	n<d<c<u
(04)	n<c<d<u	c<u<d<n	n<d<c<u
(05)	c<n<d<u	n<c<d<u	c<d<n<u
(06)	n<c<d<u	n<c<u<d	d<n<c<u
(07)	c<n<u<d	n<d<c<u	d<n<u<c
(08)	n<c<d<u	c<n<u<d	c<d<u<n
(09)	c<d<u<n	n=d<u<c	n<d<u<c
(10)	c<d<n<u	u<n<c<d	c<u<d<n
(11)	c<d<n<u	c<d<n<u	d<u<c<n

Summary table of the rank ordering for RTs on triplets with noun-noun ambiguities. Mean ranking per Priming Condition.

Priming Condition	ISI=100	ISI=500	ISI=1250
Concordant	1.3	2.4	2.3
Discordant	2.7	2.5	1.8
Neutral	2.2	2.0	2.6
Unrelated	3.8	3.1	3.3
	c<n<d<u	n<c<d<u	d<c<n<u

Aphasic Patients (N=11), Noun-Verb Ambiguities

	ISI=100 msec	ISI=500 msec	ISI=1250 msec
(01)	n<u<d<c	n<c<u<d	c<n<u<d
(02)	c<d<u<n	c<n<u<d	c<u<n<d
(03)	n<c<u<d	u<c<n<d	u<n<c<d
(04)	c<d<u<n	u<c<n<d	c<n<d<u
(05)	d<c<u<n	n<d<c<u	c<d<u<n
(06)	n<u<c<d	n<c<d<u	n<u<c<d
(07)	n<c<u<d	n<d<c<u	d<n<u<c
(08)	n<c<d<u	c<u<n<d	n<u<c<d
(09)	n<c<u<d	n<c<u<d	n<c<d<u
(10)	u<c<n<d	c<u<n<d	n<c<d<u
(11)	c<n<d<u	c<d<u<n	n<c<d<u

Summary table of the rank ordering for RTs on triplets with noun-verb ambiguities. Mean ranking per Priming Condition.

Priming Condition	ISI=100	ISI=500	ISI=1250
Concordant	2.0	1.8	2.1
Discordant	3.1	3.4	3.2
Neutral	2.1	2.1	1.8
Unrelated	2.8	2.7	2.9
	c<n<u<d	c<n<u<d	n<c<u<d

APPENDIX 3

Materials: Critical word target items used in all the experiments of chapter 4. The following information is specified for each of the 12 dominant and for each of the 12 subordinate target items: the ambiguous word, the target word, the frequency of occurrence of the target-related reading of the ambiguous word (in brackets), and the three context sentences. The context sentences are in the following order: *concordant, discordant, unrelated.*

Dominant Target Items

(1) AS - ROOK (76)
De schoonmaakster verwijderde de gemorste AS.
De metaalarbeider laste de gebroken AS.
De natuurvriend zag een zeldzame BIJ.

(2) BOK - GEIT (87)
De eigenaar van de kinderboerderij hield veel van de BOK.
De turnkampioen van het district viel hard van de BOK.
De vriendin van de filmster betaalde veel voor de JAS.

(3) BLIK - OPENER (78)
De kok stopte het afval in een BLIK.
De minnaar zocht zijn geliefde met zijn BLIK.
De brandweer haalde het katje uit de SLOOT.

(4) DAM - WATER (88)
De bevolking streed al tien jaar voor de aanleg van een DAM.
De kampioen kwam al na tien minuten in het bezit van een DAM.
Het parlement stemde al drie keer voor het veranderen van het PLAN.

(5) KRUK - STOEL (78)
De begaafde beeldhouwer zet het afgietsel op een KRUK.
De brutale bengel berooft de invalide van zijn KRUK.
De handige goochelaar haalt een konijn uit zijn BROEK.

(6) PUPIL - OOG (80)
De arts onderzoekt met een nieuw instrument de patient's PUPIL.
De violist bemoedigt met een vriendelijk gebaar de muzikale PUPIL.
De verhuizer verplaatst met een sterke takel de zware PIANO.

(7) PIJP - TABAK (84)
Mijn vader koopt ieder jaar een nieuwe PIJP.
De ingenieur inspecteert ieder kwartaal de gelaste PIJP.
De fysiotherapeut behandelt elke week mijn pijnlijke RUG.

(8) ROOSTER - SCHOOL (85)
Na luttele overweging verwerpt de conrector het nieuwe ROOSTER.
In enkele uren repareert de smid het kapotte ROOSTER.
Binnen enkele minuten bespot de clown het enthousiaste GEHOOR.

(9) SCHOT - GEWEER (99)
Midden in de nacht hoorde Marie een SCHOT.
Midden op de zolder timmerde Jan een SCHOT.
Midden op de weg vond Ronald zijn FIETS.

(10) SLINGER - KLOK (66)
Voor het feest kocht de moeder een grote SLINGER.
Aan het mechaniek bevestigde de vakman een nieuwe SLINGER.
In de ziekenboeg behandelde de fysiotherapeut de gewonde PATIENT.

(11) TRAP - TREDE (78)
De gepensioneerde glazenwasser geeft een jonge collega zijn oude TRAP.
De ijverige matroos geeft de oude scheepshond een flinke TRAP.
De handige verkoopster toont de geïnteresseerde klant een prachtige TRUI.

(12) VEER - VOGEL (74)
Jan plaagt zijn vader met een VEER.
Piet bereikt de overkant via een VEER.
Karel pakt zijn hoed van de KAST.

Subordinate Target Items

(13) AAS - KAART (17)
De winnaar speelde tenslotte zijn AAS.
Het jongetje bevestigde tenslotte zijn AAS.
De klant kocht uiteindelijk het BED.

(14) BAL - FEEST (5)
Gisteren hield de vereniging haar jaarlijkse BAL.
Gisteren kocht het meisje een mooie BAL.
Gisteren bevoer de zeiler een ruwe ZEE.

(15) BRIL - WC (7)
De loodgieter vervangt met veel vakmanschap de oude BRIL.
Marieke past met veel geduld een nieuwe BRIL.
Irma denkt met veel genoegen aan de mooie DAG.

(16) DEKEN - KERK (4)
De parochianen begroetten op grootse wijze hun nieuwe DEKEN.
De hulporganisatie kocht voor alle drenkelingen een nieuwe DEKEN.
De opzichter controleerde na het werk de nieuwe VLOER.

(17) EZEL - SCHILDER (4)
Wilma plaatste het getekende portret op de EZEL.
Herman haalde verse stro voor de EZEL.
De toerist verloor zijn nieuwe paspoort tijdens de REIS.

(18) GARDE - LEGER (18)
Tijdens het keizerlijk bezoek ontbreekt de trouwe GARDE.
In de linker keukenla ligt de nieuwe GARDE.
Onder de bijeengeraapte schillen ligt een oude DOOS.

(19) GIER - STANK (17)
In Nederland zoeken milieudeskundigen naar een oplossing voor de overtollige GIER.
In de Andes zoeken biologen naar een exemplaar van de zeldzame GIER.
Op Sicilië zoeken de bestuurders naar een subsidie voor het arme DORP.

(20) PERS - SINAASAPPEL (30)
De druiven worden verzameld in een PERS.
De ambtenaar wordt bekritiseerd in de PERS.
De winnaar wordt beloond met een KAAS.

(21) SLOT - EINDE (22)
Het moderne toneelstuk heeft een vernieuwend SLOT.
De antieke ladenkast heeft een vernieuwd SLOT.
Het plaatselijke museum bezit een unieke LAMP.

(22) STER - FILM (17)
De fans juichen uren lang voor de STER.
De geleerden turen uren lang naar de STER.
De kleuter kijkt minuten lang naar zijn DUIM.

(23) STREEK - LIST (8)
De leerling ziet zijn straf als een laffe STREEK.
De reisgids vermeldt de Borinage als een treurige STREEK.
De kunstenaar beschouwt dit stuk als zijn mooiste WERK.

(24) TON - GELD (31)
De miljonair koopt het schilderij voor een TON.
De tuinman stopt het afval in een TON.
De arts verwijdert een splinter uit de VOET.

APPENDIX 4

Materials: Critical word target items used in all the experiments of chapter 5. The following information is specified for each of the 16 noun-related items and for each of the 16 verb-related items: the ambiguous word, the target word, and the context sentences. The context sentences are presented in the following order: *concordant, concordant control, discordant, discordant control.*

Noun-related Items

(1) BERGEN - HOOG
Veel mensen zijn gecharmeerd van de BERGEN.
Veel mensen zijn gecharmeerd van de POLDER.
In dit weer is het bijna onmogelijk te beginnen met het BERGEN.
In dit weer is het bijna onmogelijk te beginnen met het HEIEN.

(2) BOEKEN - LEZEN
Mijn opa heeft een hekel aan dit soort BOEKEN.
Mijn opa heeft een hekel aan dit soort HONDEN.
Mijn vriendin heeft met veel moeite toch nog kunnen BOEKEN.
Mijn vriendin heeft met veel moeite toch nog kunnen STOPPEN.

(3) BOOG - PIJL
Na de nederlaag vertrapte Taco zijn nieuwe BOOG.
Na de nederlaag vertrapte Taco zijn nieuwe BRIL.
Men vond het niet nodig dat ik voor haar BOOG.
Men vond het niet nodig dat ik voor haar BAD.

(4) DEKKEN - SCHIP
Zij zijn heel lang bezig geweest met het reinigen van de DEKKEN.
Zij zijn heel lang bezig geweest met het reinigen van de STOEP.
Het is een hele kunst het beest te laten DEKKEN.
Het is een hele kunst het beest te laten VANGEN.

(5) FOK - ZEIL
Na terugkeer informeerde hij hoe het stond met de gescheurde FOK.
Na terugkeer informeerde hij hoe het stond met de gescheurde PEES.
Tijdens zijn bezoek vroeg hij aan mij wat ik FOK.
Tijdens zijn bezoek vroeg hij aan mij wat ik KOOK.

(6) KLINKEN - DEUR
In totaal bevestigde hij wel twaalf KLINKEN.
In totaal bevestigde hij wel twaalf KNOPEN.
Men verwacht daarop te kunnen KLINKEN.
Men verwacht daarop te kunnen GOKKEN.

(7) LEER - SCHOEN
Vroeger waren meer mensen liefhebbers van LEER.
Vroeger waren meer mensen liefhebbers van PALING.
Het zou me verbazen als ik dit ooit nog LEER.
Het zou me verbazen als ik dit ooit nog VRAAG.

(8) LIJKEN - DOOD
Heel wat mensen hebben angst voor LIJKEN.
Heel wat mensen hebben angst voor BEREN.
Zij heeft besloten dat ze niet op hem wil LIJKEN.
Zij heeft besloten dat ze niet op hem wil NEERZIEN.

(9) MAAL - ETEN
Dit was een voortreffelijk MAAL.
Dit was een voortreffelijk IDEE.
Zij wilden graag weten wat ik zoal MAAL.
Zij wilden graag weten wat ik zoal MEEN.

(10) MISSEN - KERK
Veel oudere mensen houden van de ouderwetse MISSEN.
Veel oudere mensen houden van de ouderwetse KLEDING.
Ik zou niet weten of zij hem MISSEN.
Ik zou niet weten of zij hem HATEN.

(11) PAK - KOSTUUM
Oom Hein is erg gesteld op zijn nieuwe PAK.
Oom Hein is erg gesteld op zijn nieuwe BURO.
Volgens moeder maakt het niet uit wat ik PAK.
Volgens moeder maakt het niet uit wat ik DRINK.

(12) POLSEN - HORLOGE
Harrie zegt dat hij last heeft van zijn POLSEN.
Harrie zegt dat hij last heeft van zijn GEWICHT.
Marlene beloofde mij Herman daarover te POLSEN.
Marlene beloofde mij Herman daarover te BERISPEN.

(13) ROL - TONEEL
Alle kranten schreven over deze prachtige ROL.
Alle kranten schreven over deze prachtige DAG.
Let heel goed op waarheen ik ROL.
Let heel goed op waarheen ik STUUR.

(14) TONEN - MUZIEK
Het meisje heeft moeite met de meeste TONEN.
Het meisje heeft moeite met de meeste SOMMEN.
De man wist nog niet wat hij zou gaan TONEN.
De man wist nog niet wat hij zou gaan KOPEN.

(15) LOKKEN - HAAR
Niet iedereen heeft zulke mooie LOKKEN.
Niet iedereen heeft zulke mooie TENEN.
Het valt niet mee hem daarmee te LOKKEN.
Het valt niet mee hem daarmee te PAAIEN.

(16) WIJKEN - BUURT
Er wordt tegenwoordig heel wat gedaan aan de oude WIJKEN.
Er wordt tegenwoordig heel wat gedaan aan de oude GRACHTEN.
Er zit niets anders op dan daarvoor te WIJKEN.
Er zit niets anders op dan daarvoor te TRAINEN.

Verb-related Items

(17) BEUKEN - SLAAN
Sommige mensen begonnen hard te BEUKEN.
Sommige mensen begonnen hard te GILLEN.
Oom Jan bekijkt de mooie BEUKEN.
Oom Jan bekijkt de mooie PRENTEN.

(18) BELEID/BELIJD - GELOOF
Mij werd gevraagd wat ik zoal BELIJD.
Mij werd gevraagd wat ik zoal BETAAL.
Volgens de meerderheid was dit een verouderd BELEID.
Volgens de meerderheid was dit een verouderd ONTWERP.

(19) GEBIEDEN - BEVEL
Het is niet gepast een ander te GEBIEDEN.
Het is niet gepast een ander te KASTIJDEN.
Jan en Marie houden van dezelfde GEBIEDEN.
Jan en Marie houden van dezelfde GROENTEN.

(20) GRAVEN - GAT
Het is uitgesloten dat je hier kunt GRAVEN.
Het is uitgesloten dat je hier kunt RUSTEN.
In dit gebied woonde vroeger een groot aantal GRAVEN.
In dit gebied woonde vroeger een groot aantal BEVERS.

(21) HAKEN - BREIEN
Ze weet nog niet wat ze nu zal gaan HAKEN.
Ze weet nog niet wat ze nu zal gaan VERVEN.
Ze hebben lang moeten zoeken naar deze HAKEN.
Ze hebben lang moeten zoeken naar deze DOZEN.

(22) KIEZEN - STEMMEN
Veel mensen weten niet waarom zij moeten KIEZEN.
Veel mensen weten niet waarom zij moeten VLUCHTEN.
Nellie maakt zich zorgen over de toestand van haar KIEZEN.
Nellie maakt zich zorgen over de toestand van haar KATTEN.

(23) LADEN - LOSSEN
Wij moesten alles zelf LADEN.
Wij moesten alles zelf METEN.
Alles werd teruggevonden in deze LADEN.
Alles werd teruggevonden in deze GANGEN.

(24) LANDEN - VLIEGTUIG
Het is niet mogelijk overal te LANDEN.
Het is niet mogelijk overal te FIETSEN.
Heel wat kenners gaan graag naar deze LANDEN.
Heel wat kenners gaan graag naar deze CAFE'S.

(25) VAREN - BOOT
Het valt niet mee om tegenwoordig met winst te blijven VAREN.
Het valt niet mee om tegenwoordig met winst te blijven SPELEN.
Op vakantie zag Miep een hele mooie VAREN.
Op vakantie zag Miep een hele mooie INDIAAN.

(26) PLAKKEN - LIJM
Wij zochten naar iets waarmee we konden PLAKKEN.
Wij zochten naar iets waarmee we konden SPOTTEN.
Ook Johan kreeg gisteren twee PLAKKEN.
Ook Johan kreeg gisteren twee STUIVERS.

(27) RADEN - GOKKEN
De meesten zijn er zeker van dat ik dit niet zal RADEN.
De meesten zijn er zeker van dat ik dit niet zal PIKKEN.
Tegenwoordig heeft bijna elke provincie meerdere RADEN.
Tegenwoordig heeft bijna elke provincie meerdere TAKEN.

(28) SCHUREN - SLIJPEN
In de haast had hij het vergeten te SCHUREN.
In de haast had hij het vergeten te WASSEN.
Overal zie je hier tegenwoordig grote SCHUREN.
Overal zie je hier tegenwoordig grote LEUZEN.

(29) STEEL - DIEF
Mijn ouders vinden het vervelend dat ik STEEL.
Mijn ouders vinden het vervelend dat ik STINK.
Het is niet gebruikelijk dat zo'n ding voorzien is van een STEEL.
Het is niet gebruikelijk dat zo'n ding voorzien is van een HULS.

(30) VALLEN - OPSTAAN
In deze heuvels bestaat een goede kans om onderweg te VALLEN.
In deze heuvels bestaat een goede kans om onderweg te VERDWALEN.
Naar het schijnt zit het hier vol met VALLEN.
Naar het schijnt zit het hier vol met LUIZEN.

(31) WAGEN - DURVEN
Ik weet niet of ik dat ervoor zou willen WAGEN.
Ik weet niet of ik dat ervoor zou willen LATEN.
De minister is niet erg enthousiast over deze WAGEN.
De minister is niet erg enthousiast over deze COLLEGA.

(32) ZAK - SLAGEN
Als de situatie niet verandert is het zeker dat ik ZAK.
Als de situatie niet verandert is het zeker dat ik WEGGA.
Op deze plek vond oom Piet de verdachte ZAK.
Op deze plek vond oom Piet de verdachte KIST.

SAMENVATTING

Taalstoornissen die optreden bij afasie kunnen zowel het spreken en schrijven (de taalproduktie) als het luisteren en lezen (het taalbegrip) betreffen. Het onderzoek dat in deze dissertatie gerapporteerd wordt, richt zich geheel op stoornissen in het auditieve taalbegrip. Deze stoornissen hebben tot gevolg dat de afatische luisteraar niet langer in staat is volledig te begrijpen wat tot hem of haar gezegd wordt. Het beoogde doel is nader te specificeren op welk moment tijdens het snelle maar complexe proces van taalverstaan de onderliggende stoornis optreedt en wat daarvan de preciese aard is.

Een eerste vereiste om een beter zicht te krijgen op afatische taalstoornissen is kennis omtrent het taalverwerkingssysteem zoals dat functioneert bij gezonde taalgebruikers. Centraal in het proces van taalverstaan staat het mentale lexicon. Het mentale lexicon bevat de kennis over de woorden in onze moedertaal. Deze kennis is op een of andere wijze in onze hersenen opgeslagen. De opgeslagen kennis betreft behalve de vorm van de woorden (hoe klinkt het, of hoe wordt het geschreven?), ook hun betekenis en grammaticale eigenschappen (bijvoorbeeld de woordsoort: werkwoord, zelfstandig naamwoord, enz.). Een volwassen taalgebruiker beschikt naar schatting over een passieve woordenschat van zo'n 50.000 woorden. Dat wil zeggen, wordt er een klankreeks aangeboden die met een van deze 50.000 woorden overeenkomt, dan is een volwassene in staat de daarbij horende informatie uit het mentale lexicon op te halen. Hij of zij weet in dat geval wat het woord betekent, of het een werkwoord is of een zelfstandig naamwoord, enz. Uit taalpsychologisch onderzoek is bekend dat het herkennen van een woord in een fractie van een seconde plaatsvindt. Een van de centrale vragen die een theorie over taalverstaan adequaat moet beantwoorden is dan ook: hoe zijn we in staat dit enorme databestand (het mentale lexicon) in zo'n korte tijd te doorzoeken en de juiste informatie daarin terug te vinden.

In recente taalpsychologische theorieën over taalverstaan wordt dit cognitieve proces grofweg uiteengelegd in de volgende onderdelen: lexicale toegang, lexicale selectie en lexicale integratie. Op basis van de akoestisch-fonetische eigenschappen van het geluidssignaal worden de woordvormen in het mentale lexicon geactiveerd die met de sensorische informatie overeenstemmen. Dit proces noemt men lexicale toegang. De verzameling van geactiveerde woordvormen wordt uiteindelijk gereduceerd tot één: de overgebleven woordkandidaat. Dit is het woord dat uiteindelijk door de luisteraar herkend wordt. Het inzoomen op de juiste woordvorm staat bekend als lexicale selectie. Er zijn verschillen van opvattingen over het soort informatie dat een bijdrage levert aan het proces van lexicale selectie. Volgens sommigen kan alleen de continu binnenkomende akoestisch-fonetische informatie leiden tot de reductie van het aantal geactiveerde woordvormen tot één. Anderen, daarentegen, beargumenteren dat ook contextinformatie een bijdrage kan leveren aan lexicale selectie.

Vrijwel altijd verstaan wij woorden in de context van een voortgaande conversatie. Dat wil zeggen, woorden worden meestal niet in isolatie geproduceerd, maar zijn ingebed in een zinsverband en een conversationele omgeving met haar verbale en nonverbale (bijvoorbeeld: ondersteunende gebaren) ingrediënten. Deze contextinformatie zou in principe gebruikt kunnen worden om mee te bepalen welk woord gehoord wordt. Neem als voorbeeld de zin "Ruud Lubbers steunde het voorstel van de marine om de boycot van Irak effectief te maken door het sturen van een tweetal sche...". Op het moment dat wij de eerste lettergreep van het laatste woord gehoord hebben, kunnen we op grond van de informatie in de voorafgaande zinscontext voorspellen dat de spreker *schepen* gaat zeggen en niet *schedels*. Met andere woorden, zelfs voordat we alle akoestisch-fonetische informatie ontvangen hebben die nodig is om het woord *schepen* eenduidig te herkennen, zou de contextinformatie ertoe kunnen leiden dat *schepen* reeds geselecteerd wordt, terwijl andere geactiveerde woordvormen, zoals *schedels*, worden gedeactiveerd. Op welk moment van woordherkenning contextinformatie een rol gaat spelen is een centrale vraag in taalpsychologisch onderzoek.

Het ontwerp van het taalverwerkingssysteem is er echter niet op gericht woordvormen te herkennen. Waar het de luisteraar om gaat, is te begrijpen waar de spreker het over heeft. Dat wil zeggen de processen van lexicale toegang en lexicale selectie moeten er uiteindelijk toe leiden dat de met geactiveerde woordvormen gelieerde woordbetekenissen beschikbaar komen. Deze moeten vervolgens met de betekenissen van de voorafgaande woorden tot de interpretatie van de gehele uiting worden samengesmeed. Het incorporeren van de geactiveerde woordbetekenis in de representatie van de voorafgaande context wordt aangeduid met de term lexicale integratie. Aldus is het proces van auditieve woordherkenning te omschrijven als het projecteren van geluid op een woordbetekenis in het mentale lexicon, met als doel de woordbetekenis te laten oplossen in een betekenisrepresentatie die de gehele uiting van de spreker omvat. Een voorwaarde om zover te komen is dat de processen van lexicale toegang, lexicale selectie en lexicale integratie in de tijd nauwkeurig op elkaar zijn afgesteld. De voor deze onderlinge afstelling kritische tijdspanne ligt eerder in de orde van milliseconden dan van seconden. Als deze processen ongestoord en met de vereiste onderlinge temporele afstemming verlopen, heeft de luisteraar begrepen wat de spreker hem of haar meedeelde.

Het in deze dissertatie gerapporteerde onderzoek beoogt na te gaan of taalbegripsproblemen bij afasiepatiënten te wijten zijn aan stoornissen in lexicale toegang, lexicale selectie of lexicale integratie, dan wel in de onderlinge afstemming van deze processen. Teneinde daarover uitspraken te kunnen doen moet voor een experimentele aanpak gekozen worden die de onderzoeker in staat stelt het proces van taalverstaan te registreren terwijl het zich afspeelt. Meestal wordt in onderzoek naar taalbegripsstoornissen gepoogd de adequaatheid van de uiteindelijke interpretatie van de taaluiting vast te stellen. Patiënten krijgen in zo'n geval veelal een zin te lezen of te horen, waarbij zij vervolgens uit een aantal plaatjes dat plaatje moeten kiezen dat met de in de zin beschreven situatie overeenkomt. Op grond van de fouten die de patiënten daarbij maken worden conclusies getrokken over de aard van de taalbegripsstoornissen. Voor een beter begrip van mogelijke afwijkingen in de temporele organisatie van het taalverstaan is dit type onderzoek echter ontoereikend. Daarvoor moeten we het proces kunnen volgen zoals dat zich afspeelt in de tijd, milliseconde voor milliseconde. Experimentele taken die wel aan deze eis voldoen worden 'on-line' taken genoemd. Daarin wordt meestal van de patiënt of proefpersoon gevraagd zo snel mogelijk op een bepaald aspect van de aangeboden uiting te reageren. Op basis van het daaruit resulterende patroon van reactietijden kunnen gevolgtrekkingen gemaakt worden over de temporele organisatie van het taalverstaan. De experimenten die in deze dissertatie beschreven worden maken gebruik van 'on-line' taken teneinde de centrale vraagstelling te kunnen beantwoorden.

Een ander hulpmiddel waarvan in de experimenten gebruik gemaakt wordt zijn ambigue woorden. Dit zijn woorden met meerdere, geheel verschillende betekenissen. Het woord *bank* is daarvan een voorbeeld. Dezelfde klank- of letterreeks verwijst in dit geval zowel naar een meubelstuk als naar een instelling waar men zijn geld deponeert. Welk van beide betekenissen door de spreker bedoeld wordt kan slechts op grond van de context worden uitgemaakt. Dus als we de zin horen "Alvorens Jan zijn nieuwe auto kon ophalen, moest hij naar de bank", wordt het daarin voorkomende woord *bank* door vrijwel iedereen als geldinstelling opgevat. Deze lezing van het woord *bank* wordt door de context als het ware opgedrongen, zozeer zelfs dat het de meeste luisteraars niet opvalt dat we hier te maken hebben met een woord dat twee geheel gescheiden betekenissen heeft. Ambigue woorden komen in de taal met een zekere regelmaat voor zonder dat taalgebruikers zich doorgaans van hun meerduidigheid bewust zijn. Des te opmerkelijker is het dat uit taalpsychologisch onderzoek is gebleken dat ook in zinscontexten die een van beide betekenissen 'opdringen', in eerste instantie niet alleen de opgedrongen, maar ook de andere betekenis geactiveerd wordt. In het geval van het bovenstaande voorbeeld wordt dus niet alleen de betekenis van bank als geldinstelling maar ook die van bank als meubelstuk geactiveerd. Vrijwel onmiddellijk nadat de beide betekenissen van het ambigue woord geactiveerd zijn (dat wil zeggen binnen 200 milliseconden nadat we het woord gehoord hebben), verdwijnt de activatie van de betekenis die niet in de context past, en blijft alleen de betekenis over die door de context wordt opgedrongen. Hoewel alle betekenissen van een ambigu woord dus in eerste instantie worden geactiveerd, vindt op basis van de contextinformatie zeer snelle selectie plaats van de meest passende betekenis. Omdat in dit geval de diverse woordbetekenissen een gemeenschappelijke woordvorm hebben, kan betekenisselectie niet plaatsvinden op basis van akoestisch-fonetische informatie. Alleen de uitkomst van het lexicale integratieproces bepaalt onder deze omstandigheden wat de meest passende betekenis is. Deze betekenis wordt geselecteerd als uitkomst van de pogingen de verschillende woordbetekenissen met de context te integreren.

In mijn onderzoek heb ik ambigue woorden als hulpmiddel gebruikt om het tijdsverloop van toegang tot en integratie van woordbetekenissen in het niet langer optimaal functionerende taalverwerkingssysteem van afasiepatiënten te onderzoeken. Een tweetal variabelen waren daarbij essentieel. Allereerst het moment waarop de activatie van de verschillende betekenissen van ambigue woorden gemeten werd. In alle experimenten werd betekenisactivatie gemeten onmiddellijk na het ambigue woord (i.c. 100 milliseconden na woordeinde), en na een langer interval, in duur variërend van 500 milliseconden tot 1200 milliseconden. Op deze wijze kon worden nagegaan of selectie van de juiste betekenis plaats vond en zo ja, of dit op dezelfde snelle, efficiënte wijze gebeurde als in het intacte taalverwerkingssysteem.

Een tweede relevante variabele was de aard van de context die aan het ambigue woord voorafging. Door de aard van deze context te variëren, kon worden nagegaan of verschillende vormen van contextuele informatie met dezelfde efficiëntie konden worden benut bij het selecteren van de juiste betekenis. Naast zinssemantische informatie maakt de luisteraar tijdens het proces van betekenisselectie ook gebruik van de syntactische contextinformatie. Om het tijdsverloop van betekenisselectie op basis van syntactische contextinformatie te bepalen, gebruikte ik in enkele experimenten ambigue woorden waarvan de verschillende betekenissen geassocieerd zijn met verschillende woordsoorten. Het woord *kussen* is daarvan een voorbeeld. In de betekenis van een 'met veren, schuimplastic enz. gevulde zak die dient om het lichaam of een deel ervan zacht te ondersteunen' hebben we te maken met een zelfstandig naamwoord. In de betekenis van 'zoenen' is het een werkwoord. Indien we de context zo veel mogelijk ontdoen van een semantische bevoordeling van een der betekenissen, moet selectie tot stand komen via de woordsoort die door de syntactische context wordt toegelaten. Zo kan in de zin "Hij denkt er niet aan om dat te wagen", de lezing van *wagen* als 'vervoermiddel' niet zozeer worden uitgesloten op grond van de betekenis van de voorafgaande woorden als wel omdat de syntactische structuur van de zin in die positie een zelfstandig naamwoord verbiedt terwijl een werkwoord is toegestaan. De syntactische structuur van de zin bepaalt in dit geval dat we te maken hebben met *wagen* in de betekenis van 'durven' en niet in de betekenis van 'vervoermiddel'. Een derde soort context is die welke bestaat uit losse woorden. Hierbij is betekenisselectie op basis van zinsinformatie uitgesloten. In woordparen als 'poes-kater' en 'bier-kater' vindt de selectie van de juiste betekenis plaats op basis van de onderlinge betekenisrelaties van afzonderlijke woorden in het mentale lexicon. Betekenisselectie in deze contexten kan ons iets leren over de wijze waarop woordbetekenissen in het mentale lexicon onderling verbonden zijn.

Het experimentele programma dat van het bovenstaande instrumentarium gebruik maakte had ten doel een aantal mogelijke oorzaken van taalbegripsstoornissen bij bepaalde vormen van afasie experimenteel op het spoor te komen, dan wel uit te sluiten. Een eerste mogelijke oorzaak van een verminderd taalbegrip is het verloren gaan van bepaalde vormen van kennis die nodig zijn om de gehoorde uiting te kunnen interpreteren.

Een lang gekoesterde gedachte is dat bij patiënten met ernstige stoornissen in het taalbegrip (i.c. patiënten met een afasie van Wernicke) de aan de afasie ten grondslag liggende hersenbeschadiging een groot deel van de kennis over woordbetekenissen heeft uitgewist. Het mentale lexicon is qua inhoud en structuur aangetast. Deze voor de hand liggende gedachte is echter niet de enig mogelijke oorzaak. Een alternatieve mogelijkheid is dat kennis van woordbetekenissen niet verloren is geraakt, maar dat de processen om deze kennis uit het mentale lexicon op te halen verstoord zijn. Met andere woorden, een snelle en automatische toegang tot woordbetekenissen is door de hersenbeschadiging niet langer mogelijk. Recent onderzoek heeft laten zien dat begripsstoornissen van lexicaal-semantische aard wellicht eerder met een probleem in het ophalen van woordbetekenissen uit het lexicon van doen hebben dan dat deze veroorzaakt worden door het uitwissen van lexicale informatie.

In hoofdstuk 3 beschrijf ik een reeks experimenten die nader ingaan op de kwestie van verloren kennis of verstoorde toegang. In deze experimenten werd verrassend genoeg noch voor het verloren gaan van woordbetekenissen, noch voor een blokkade in de automatische toegang tot woordbetekenissen enige evidentie gevonden. Zowel patiënten met een afasie van Broca als patiënten met een afasie van Wernicke blijken in staat op grond van akoestisch-fonetische informatie woordbetekenissen in het mentale lexicon te activeren. Dit suggereert dat stoornissen in het taalverstaan niet veroorzaakt worden door een onvermogen automatisch toegang te verkrijgen tot lexicaal-semantische kennis, maar veeleer ontstaan in de daarop volgende fase waarin woordbetekenissen worden geïntegreerd in de context. Deze mogelijke oorzaak van taalbegripsstoornissen werd meer specifiek onderzocht in een reeks experimenten die in de hoofdstukken 4 en 5 gerapporteerd worden.

In de hoofdstukken 4 en 5 wordt nagegaan of patiënten bij het selecteren van de juiste betekenis adequaat en snel gebruik kunnen maken van de semantische en syntactische informatie in de zinscontext. Uit de resultaten van de uitgevoerde experimenten blijkt dat patiënten met een afasie van Broca weliswaar in staat zijn beide vormen van informatie te gebruiken om het proces van lexicale selectie tot een succesvol einde te brengen, maar dat in vergelijking met het intacte taalverwerkingssysteem er een vertraging optreedt in het tijdstip waarop het selectieproces is voltooid. Dit duidt op een afwijking in de fijne temporele afstelling van de processen van lexicale toegang en lexicale integratie. Het kost de patiënten meer tijd de geactiveerde woordbetekenissen in de zinscontext te integreren. Omdat het tempo waarin de sensorische informatie binnenkomt gelijk blijft, levert de vertraging in lexicale integratie uiteindelijk problemen op bij het tot stand brengen van een interpretatie van uitingen die uit meer dan enkele woorden bestaan.

De patiënten met een afasie van Wernicke blijken in het geheel niet in staat de zinssemantische contextinformatie te gebruiken om de passende betekenis te selecteren. Dit suggereert dat de ernstige taalbegripsstoornissen waaraan deze patiënten veelal lijden het gevolg zijn van het onvermogen de op basis van sensorische informatie geactiveerde woordbetekenissen met voorafgaande woordbetekenissen te integreren tot een betekenisrepresentatie die de gehele uiting omvat.

Indien men de uitkomsten van de uitgevoerde experimenten in zeer globale zin samenvat, leiden deze tot de conclusie dat stoornissen in het taalverstaan zoals die optreden bij een afasie van Broca of een afasie van Wernicke te maken hebben met een falend of minder optimaal verlopend proces van lexicale integratie. In hoofdstuk 6 wordt nagegaan waaraan de selectieve stoornis in het proces van lexicale integratie toegeschreven moet worden. Daarin wordt de gedachte ontwikkeld dat de vertraging in lexicale integratie samenhangt met een reductie in de verwerkingscapaciteit voor talige processen. Zoals alle cognitieve processen, vereist ook taalverstaan een bepaalde hoeveelheid verwerkingscapaciteit. Daarbij kan gedacht worden aan de geheugenruimte die nodig is om tussenresultaten van het proces van taalverstaan tijdelijk op te slaan, maar ook aan de mentale energie die nodig is om complexe mentale operaties met de vereiste snelheid te laten verlopen. Naarmate een bepaalde mentale operatie een groter beroep doet op de beschikbare hoeveelheid verwerkingscapaciteit, zal een reductie daarvan ernstiger gevolgen hebben. In hoofdstuk 6 beargumenteer ik dat het proces van lexicale integratie een groter beroep doet op de beperkte verwerkingscapaciteit dan het proces van lexicale toegang. Terwijl in het laatste geval alleen verwerkingscapaciteit nodig is om in het geheugen opgeslagen kennis (i.c. woordbetekenissen) op te halen, vereist lexicale integratie dat een contextrepresentatie in een geheugenbuffer gehouden wordt en de passendheid van alle geactiveerde woordbetekenissen berekend wordt. De experimentele bevindingen laten zich het best verenigen met de gedachte dat een verminderd vermogen tot het begrijpen van taal bij patiënten met een afasie van Broca of een afasie van Wernicke samenhangt met een reductie in de voor taalverstaan vereiste verwerkingscapaciteit. Deze reductie in verwerkingscapaciteit heeft met name gevolgen voor het proces van lexicale integratie. Dit proces is ofwel vertraagd (in patiënten met een afasie van Broca), ofwel niet langer mogelijk (in patiënten met een afasie van Wernicke).

CURRICULUM VITAE

Hoewel op de kleuterschool door de peuterleidster nog aan zijn verstandelijke vermogens getwijfeld werd, slaagde de auteur er desalniettemin in de lange mars door de onderwijsinstituties in de vorm van de lagere school, het gymnasium β en de universiteit met goed gevolg te doorlopen. Gesterkt door de goede afloop wist hij zich na enige omwegen een promotieplaats op het Max-Planck-Institut für Psycholinguistik te verwerven. Het in dat kader uitgevoerde onderzoek resulteerde in de achterliggende proeve van bekwaamheid.

EPILOGUE

May I remind those of you who have read this thesis from cover to cover, and who have by now reached the conclusion that it contains far too many words, of the following:

"You never know what is enough unless you know what is more than enough."

William Blake
In *Proverbs of Hell* (1793).

STELLINGEN

behorende bij het proefschrift

Tracking the time course of language understanding in aphasia

1 De term 'adaptatietheorie' is uitsluitend van toepassing op het samenstel van proposities dat een verklaring poogt te geven van de wijze waarop afasiepatiënten hun taalhandicap compenseren In dat licht suggereert de omschrijving van de adaptatietheorie als "a new theory of grammatical impairment in aphasia" (Kolk, 1987) ten onrechte dat deze de onderliggende stoornis in het taalverwerkingssysteem van afasiepatiënten verklaart

2. Het zou de cognitieve neuropsychologie ten goede komen indien gevalstudies en computersimulaties van cognitieve stoornissen een breed bereik aan empirische data als toetssteen voor de houdbaarheid van het voorgestelde theoretisch model hanteren, in plaats van een zeer beperkte verzameling empirische gegevens als illustratieve ondersteuning daarvoor aan te voeren

3. Het tekort aan biologische plausibiliteit voor de huidige generatie van connectionistische modellen wordt niet gecompenseerd door de knopen in een dergelijk model neuronen te noemen, patronen van activatie te voorzien van de predicaten excitatoir en inhibitoir, en aan de term 'netwerk' het adjectief 'neuraal' toe te voegen.

4. De enorme vooruitgang van 'brain-imaging' technieken in het afgelopen decennium opent de mogelijkheid van een cognitieve neurowetenschap waarin neuroanatomie en neurofysiologie substantieel bijdragen aan onze kennis van menselijke cognitie. In tegenstelling tot de opvatting van Churchland (1989) impliceert dit echter geenszins dat in zo'n geval noties ontleend aan de volkspsychologie geheel en al de geest zullen geven in verklaringen van menselijke cognitie.
(Churchland, P. M. (1989). *A neurocomputational perspective The nature of mind and the structure of science*. Cambridge, MA. MIT Press).

5. Niet alleen psychologisch, maar ook neurofysiologisch onderzoek suggereert dat coördinatie van deelactiviteiten in het tijdsdomein een structurerend principe is voor diverse vormen van cognitie
(Gray C.M., Konig, P, Engel, A.K., & Singer, W. (1989) Oscillatory responses in cat visual cortex exhibit inter-columnar synchronization which reflects global stimulus properties. *Nature, 338*, 334-337.)

6. Een belangrijke, doch zelden genoemde drijfveer achter het propageren van 'single-case' studies in de neuropsychologie, is terug te voeren op het uit de economie bekende streven naar winstmaximalisatie. Beoogd wordt in dit geval het doen stijgen van de publicatie-patiënt ratio.

7 De ondergang van het reeel bestaande socialisme in Oost-Europa illustreert dat ook politieke ideologieen zich niet kunnen veroorloven de reeel bestaande determinanten van menselijk gedrag te veronachtzamen

8. Alvorens te besluiten een boek aan een geliefd persoon op te dragen, dient de auteur zich ervan te vergewissen dat de kwaliteit van het geschrevene niet onderdoet voor de kwaliteit van degene aan wie het wordt opgedragen

9. Sommige theorieen verliezen veel van hun aantrekkingskracht wanneer men de aanhangers ervan leert kennen

10. De relatie tussen de gebaren en de woorden van Erwin Kroll is ongeveer even sterk als die tussen de weersvoorspelling en het weer

11 Ook onder wetenschappers geldt onverkort de dichtregel van Lucebert. "Er is geen honger naar trompetten als gordijnen"

Peter Hagoort
Nijmegen, 13 november 1990

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